




Annual Report
2021

भाकृअनुप
ICAR

ICAR Research Complex for Eastern Region
ICAR Parisar, P.O.: Bihar Veterinary College
Patna- 800 014 (Bihar)

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Preface

It is a great pleasure for me to present the 21st Annual Report of the institute for the year 2021, focusing the significant research achievements and activities of the Institute. The Institute undertakes multi-disciplinary and multi-commodity research to enhance the productivity of agricultural systems through efficient management of available natural resources, and demonstration as well as dissemination of developed technologies in diverse agro-ecological zones of eastern region. The Institute has developed several viable technologies during the period under report for enhancing food and nutritional security and farmers' income in the region focusing mainly on smallholders and landless production system including tribal farming system. Several health and agro-advisories are provided to the farmers of the region to cope up with the situation. Emphasis has been given on development of stress tolerant crop varieties, management of rice-fallows, popularization of resource conservation technologies, integrated farming system mode of food production, crop diversification and carbon sequestration, water productivity enhancement, mechanization of small farms, weed management, restoration of degraded lands, solar energy application in agriculture, characterization of indigenous livestock and poultry resources, management of animal health and zoonotic diseases, feed& fodder production, integrated fish farming systems, etc. Two high yielding multiple stress tolerant rice varieties have been notified and released by Central Sub-Committee and other by the State Sub-Committee, Uttar Pradesh. Five rice genotypes have also been promoted from IVT to AVT 1 trial under AICRP programme. In order to strengthen the plant genetic resource management, promising genotypes of different fruits and improved lines of makhana, water chestnut, and pulses like lentil, chickpea and grass pea have been identified. Besides, quality seeds of rice, pulses, vegetables, planting materials of fruits and flowers were produced and provided to the end users. Studies on agricultural production under natural and organic farming, nutri-garden and nutri-cereals production have been concentrated in different agro regions of eastern India. During the period the institute has worked significantly on conservation agriculture, carbon footprint of different crops, rice fallow management and water productivity assessment of various crops and cropping systems. Under the DBT Biotech KISAN Hub project, technology demonstration on cultivation of high value horticultural crops has been undertaken in four districts of Jharkhand and three districts of Bihar. Four Farmer Producer Organization (FPO) have been formed to facilitate the agriculture produce. Two MoUs have been signed for large scale seed production of open pollinated varieties and grafted plants of brinjal and tomato while under the ABI project, three entrepreneurs have been registered as Incubatees.

Studies on fish productivity, water quality, plankton density, etc. in fish-based integrations have been undertaken. Breeding techniques of minor carp have been studied. The Institute has also been providing IT based technological support to the farmers, extension workers and state officials through its extensive extension network. Climate resilient technologies have been demonstrated in 37 villages to improve the adaptive capacity of farmers to cope with the climate risks. A total of 165 training programmes, 21 Front Line Demonstrations, and 14 On Farm Trials have been conducted for the farmers and the state government officials. Thirty seven villages of six districts of Bihar and Jharkhand were covered under 'Mera Gaon Mera Gaurav' to make the farmers aware of improved technologies. During the period under report, the institute has published 113 research papers in the journals of national and international repute, 2 books, 26 book chapters, 7 bulletins, 12 extension folders and 68 popular articles. I place on record my sincere gratitude to Dr. T. Mohapatra, Secretary DARE and Director General, ICAR for his unstinted guidance and support in executing the mandate of the Institute. The encouragement, valuable guidance and support rendered by Dr. S.K.Chaudhari, DDG (NRM) and Dr. S. Bhaskar (ADG, AAF&CC) are duly acknowledged. All Heads of the Divisions/Research Centres deserve appreciation for submitting their research findings in time. I also express my appreciation to the Editorial team and other staff members of the institute for compiling and bringing out this report in time.

(Ashutosh Upadhyaya)
Director (Acting)

Content

1. Executive Summary

The salient achievements of the institute during 2021 are summarized below:

- A high yielding multiple stress tolerant rice variety Swarna Unnat Dhan (IET 27892) has been released and notified for cultivation under irrigated transplanted condition in the states of Bihar, Odisha, West Bengal, Madhya Pradesh and Maharashtra. It is an early duration (115-120 days), high yielding (5.0-5.5 t/ha) having long slender grain type, multiple stress (drought, disease and insect pest) tolerant with desirable cooking quality.
- A high yielding multiple stress tolerant rice variety Swarna Sukha Dhan (IET 24692) has been released and notified for cultivation under direct seeded condition in drought prone rainfed areas of Uttar Pradesh. It is an early duration (110-115 days), high yielding (3.5-4.0 t/ha), multiple stress (drought, disease and insect pest) tolerant, with desirable grain and cooking quality traits with high level of desired micronutrient (Zinc:23.1ppm) content and having medium slender grain type.
- Five rice genotypes RCPR 61 (IET 28378), RCPR 68 (IET 29036), RCPR 70 (IET 29405), RCPR 71 (IET 29427) and RCPR 75 (IET 29243) have been promoted from IVT to AVT 1 and two rice genotypes RCPR 60 (IET 28329) and RCPR 63 (IET 28631), have been promoted from AVT 1- to AVT 2 trial after second year of testing under AICRP program.
- Rice genotypes, IR 102796-14-77-2-1-2, IR 96321-558-563-B-2-1-1, IR 102777-18-64-1-2-6, IR 96321-315-294-B-1-1-1, RCPR 10 and IR 96321-315-323-B-3-1-3 have been found promising for multiple stresses (submergence and drought) tolerance with productivity range of 1.14-1.52 t/ha as compared to check variety Swarna Sub 1(0.870 t/ha).
- Rice genotypes, IR 84899-B-183-20-1-1-1, IR93827-29-2-1-1-3, IR93827-29-1-1-2, IR 93827-29-1-1-3, IR 84899-B-179-13-1-1-1, IR83929-B-B-291-2-1-1-2, IR84899-B-182-3-1-1-2 have been identified promising for multi-stages drought tolerance with productivity range of 2.34-2.78 t/ha as compared to Sahbhagi Dhan (1.624 t/ha).
- In chickpea, one entry 'DBGC 3' has been promoted during 2021 from IVT to AVT-1 of AICRP on Chickpea for timely sown condition. This genotype matures in 135-140 days and has yield potential of 3.5 t/ha with 100 seed wt of 25 g under normal sown condition.
- In yardlong bean, bicolour seed coat coloured genotype RCPY-2 has been identified as high yielding (1036.66±115.9 g/plant) and disease resistant. In dolichos bean, a genotype RCPD-1 which is bush type, photo-insensitive, early flowering (40 days), prolific bearer (130-150 pod per plant) with flattened dark green vegetable type pod has been selected. Genotype RCPD-15 has been identified as prolific bearer and anthocyanin rich with the morphological marker (dense pubescence on pod surface).
- Breeder seed (98.9 q), nucleus seed (2.75 q) and truthfully lebelled seed (72 q) of rice varieties Swarna Shreya, Swarna Shakti Dhan and Swarna Samriddhi Dhan have been produced by ICAR RCER, Patna during *kharif* 2021.
- More than 10 q quality seeds of rice varieties (Swarna Shreya, Swarna Shakti Dhan and Swarna Samriddhi Dhan) have been distributed to more than 250 farmers belonging to different districts of Bihar and Jharkhand during 2021 for demonstration and on-farm testing.
- Under pulse seed hubs, a total of 36.32t of quality seeds of different varieties of pulses (red gram, chickpea, lentil, moongbean and urdbean) have been produced and sold to different stakeholders including Bihar Rajya Beej Nigam during the year 2021.
- In pathological trials at Tirhut College of Agriculture, Dholi (Muzaffarpur), 4 genotypes of chickpea (DBGC 1, DBGC 3, DBGC 4 and RCEC 2310) and two genotypes of lentil (DBGL 62 and DBGL 105) expressed resistant to moderately resistant reaction against chickpea wilt and lentil wilt, respectively. In lentil, the genotype 'RCEL 19-1' showed mortality percent substantially more than the susceptible check 'Sehore 74-3', indicating that it could be a better susceptible check than the existing one for

assessing wilt sick reaction of lentil genotypes in AICRP pathological trial.

- Sheath blight pathogen (*Rhizoctonia solani*) was isolated from infected rice plant. Pathogen was morphologically characterized and submitted to Indian Type Culture Collection (ITCC), ICAR-Indian Agricultural Research Institute, New Delhi. Besides, ITS based sequencing of *Rhizoctonia solani* has been done and submitted to NCBI database.
- Forty-Yard-long bean (*Vigna unguiculata*) genotypes were screened against yellow mosaic disease in natural conditions. Genotypes RCPY-1, RCPY-2, RCPY-4, IC622601, LCM-5, IC626154 and IC626152 were found to be resistant.
- Adoption of CA (partially or fully) improved the soil physical health in terms of increased aggregate stability (11-12%), increased water infiltration, higher volume of macropores and lower bulk density (4.7-5.6%) particularly in surface soil layer (0-10 cm depth). Complete CA (S3: ZTDSR-ZTW-ZTM) practices showed greater amount of total soil organic carbon (27-35%), passive pool of C and higher system productivity (38-53%).
- In rice-wheat-mungbean system, 10.8% and 14-36% higher net returns and energy productivity, respectively were noted with CA-based practices as compared to conventional tillage. CA-based system (ZTDSR-ZTW-ZTM) was helpful in reducing weed flora and soil weed seed bank as compared to conventional tillage.
- Crop diversification and intensification of rice-fallows with inclusions of early duration and high yielding pulses/oilseed crops (chickpea, lentil, safflower) were found viable options for horizontal expansions of area for pulses/oilseeds apart from improving overall system productivity.
- Among the nutri-cereals, jowar (3427 kg/ha) and bajra (2887 kg/ha) as major and barnyard millets (2060 kg/ha), ragi (1925 kg/ha) and kodo millet (2045 kg/ha) as minor nutri-cereals were found more productive when planted within 15th July. Based on local preferences bajra as major nutri-cereal and ragi & barnyard among minor nutri-cereals have been identified for upscaling.
- In Nutri Garden model, the highest yield potential was found in cropping pattern carrot-bottle gourd-water spinach (44.1±11.1 kg) followed by broccoli-Yard Long Bean (YLB)-Okra (43.9±7.7 kg) and spienach-YLB-Sponge gourd (42.4±5.7 kg). Nutrition-wise, highest energy (23892 Kcal), protein (1849.9 g) and fat (143.2 g) were found in YLB- Pea-Red Amaranth cropping pattern.
- Diversification of wheat with vegetables like cauliflower and broccoli was found remunerative than rice-wheat- greengram system. Rice – cauliflower - spinach - greengram system produced significantly higher system productivity (34.80 t/ha), net return (Rs. 337355 per ha) and benefit cost ratio (2.83) among all cropping systems followed by Rice-broccoli-leafy onion-greengram system (32.15 t/ha; Net Return: Rs.291752 & B:C:2.74).
- Under one acre IFS model, field crops in combination with poultry + mushroom + goatry fetched the highest net income of Rs. 90,353/annum, which was about 3.2 times higher than rice-wheat cropping system. Besides, 1.46 t of vermicompost, 0.9 t of green manure and 0.72 t of poultry manure were produced; these were equivalent to 103 kg of urea, 230 kg of SSP and 68 kg of MOP. An Additional employment of 79 man-days was also generated through the system.
- Under two-acre IFS model, livestock (2 cows + 2 calves), fisheries, duckery, and vegetables and fruits were integrated with crop (rice-wheat, rice-maize, rice-lentil and rice-mustard as cropping system). Rice-wheat + vegetables + livestock + fisheries + duckery IFS model gave the maximum net return by Rs. 1,56,280/annum with additional employment opportunity of 160 man-days.
- Waste recycling within the integrated farming system has added an ample amount of OM and increase in organic carbon upto 7.8%, N 14.6%, P 12.7% and K 13.5% in the soil over a period of ten years. Net GHG emission from one acre model (Crop + Goat +Poultry) was -1457.6kg Co2- e while under two-acre IFS model it was -2670 kg Co2- e.
- Rice-Cauliflower-Greengram and Jowar- chickpea –fallow cropping systems had shown most diverse weed species during *kharif* (11 and 10 *species*) and *rabi* season (14 and 12 spp.), respectively.
- Under weed seed dynamics study, irrespective of cropping system, lower soil layer i.e. 10-20 cm depth had recorded higher weed count (21.4/m^2) compared to upper/surface soil depth i.e. 0-10 cm (12.7/m^2) except orchard crops where more weed seed count were recorded at 0-10cm of soil in both the seasons.
- The N-leaching loss in tomato could be minimized to the tune of 12.3 and 6 kg ha^{-1} with a simultaneous saving of K-fertilizer to the magnitude of 8.6 and 3.8 kg ha^{-1} by the adoption of organic and integrated

nutrient management practices, respectively. However, adoption of organic and integrated nutrient management practices in pea reduced the N-leaching loss by 3.7 and 2.2 kg ha^{-1}, while K-leaching loss by 3.6 and 1.4 kg ha^{-1}, respectively.

- Application of Spinosad 45SC @ 70 g *a.i.*/ha, emamectin benzoate 5SG @ 11 g *a.i.*/ha, imidacloprid 200SL @ 40 gm*a.i.* ha^{-1} and fipronil 5SC @ 30 g *a.i.* ha^{-1} has been observed effective to manage chilli thrips, *Scirtothrips dorsalis* on rotational basis in the chilli ecosystem.
- Water productivity can be enhanced from existing Rs. 27.90 /m^3 from 6703 ha area to Rs. 32.42 /m^3 from 4700.13 ha area in the command area of Paliganj distributary and existing Rs. 34.03 /m^3 from 958 ha area to Rs. 42.25 /m^3 from 937.22 ha for the Nalanda corridor project site if the area under different cereal and horticultural crops is optimally allocated.
- Irrigation water price for rice, *kharif* maize, wheat, lentil, khesari, gram, *rabi* maize, potato, onion and green gram crops was assessed (Rs./m^3) as 3.73, 22.60, 11.67, 21.50, 27.42, 23.27, 14.75, 98.06, 84.92, and 27.17, respectively, when irrigation was applied through canal and tube well in Paliganj distributary. Similarly, for the Nalanda Corridor project site (groundwater irrigated area), irrigation water price for rice, *kharif* maize, wheat, lentil, gram, pea, mustard, potato, *rabi* maize, and green gram crops was assessed (Rs./m^3) as 12.54, 24.61, 18.71, 44.15, 39.53, 37.85, 32.35, 96.93, 15.44, and 30.25, respectively.
- The irrigation command area of 1.0 HP, 2.0 HP and 3.0 HP solar pumps on daily, weekly and fortnightly basis were assessed as 1.0, 1.3 and 2.4 ha, respectively.
- The highest grain yield of rice 6.04 t/ha and 5.90 t/ha were achieved with two foliar sprays of Nano DAP @ 4 ml/l (T_{10}) and 2 ml/l (T_9) with 50% conventional DAP fertilizer. Study indicated that the Nano-DAP could save up to 50% of conventional DAP dose without affecting grain yield.
- Flood mapping study showed that in Bihar about 26073.0 km^2 area is flood-prone and about 75.0% of that is in the North Bihar alone. Zoning of the flood hazard area as per its flood vulnerability revealed about 525.1 km^2 area of Bihar under very high risk, 804.1 km^2 under high risk, 2461.6 km^2 under moderate risk, 5738.2 km^2 under low risk and 16544.0 km^2 under very low risk zone.
- Pigeonpea genotypes, ICAR RCER PP 01, ICAR RCER PP 02, ICP 9353, ICP 9516, ICP 9228, ICP 9397 and IPAC-79 were identified to tolerate submergence for 1687 hrs in two spells with more than 50% survivability.
- In linseed, the highest seed yield (1477 kg/ha) and biological yield (4610 kg/ha) were recorded when three irrigations were applied. Highest water productivity of 1.28 kg/m^3 was recorded in rainfed crop while, lowest of 0.81 kg/m^3 was recorded when three irrigations were applied.
- Water balance components in paddy employing drum culture technique were assessed during *kharif* 2021. Percolation beyond the root zone, water losses through evapotranspiration and water stored in the root zone were computed as 35.36%, 49.77%, and 14.87%, respectively of total water applied. Their crop coefficient values were 1.08, 1.19, 1.29, 1.25 and 0.95 for tillering stage, panicle initiation, flowering, physiological maturity and harvesting stage, respectively.
- The ergonomic study on modified and local axe indicated that the energy expenditure for modified axe was lower (9.33 kJ/min) than local axe (10.12 kJ/min). The modified axe reduced drudgery by 27.96% and efficiency increased by 7.81%. Similarly, ergonomic study on modified spade indicated 38.33% reduction in drudgery, 8.39% increase in efficiency and 5.44% more output as compared to local spade.
- Eleven species of arthropod of insects were identified in makhana fields. Root borer Singhara Beetle and Aphids were found to be major pests of Makhana.
- Peripheral Vacant Space Model was developed to assess the fish diversity and production potential in lentic inland ecosystem of North Bihar. An additional income of 30-40% can be secured by integrating culture of fish (carp composition in the ratio of 4:4:1:1 of catla, rohu, mrigal and common carp/silver carp, respectively) with makhana as compared to mono fish culture system.
- Fourteen different sizes (grades) of makhana seeds were collected from the makhana fields. The weight of one seed having maximum size of 14.23 mm was 1.36 g while the weight of the lowest size (7.34 mm) seed was 0.24 g. There was a linear relationship between size of seed and yield potential i.e., higher the size of seed higher is the yield.
- Analysis of 11 composite soil samples collected from the makhana fields of north Bihar showed organic carbon status in the range of 0.38% to 0.93%, whereas makhana yield ranged from 1.6 to

3.4 tons per hectare. Regression analysis showed the yield improvement of 3.3 quintals/ha for every 0.1 percentage point increase in SOC (R^2=0.83), implying that soil organic carbon content is an important determinant of makhana productivity.

- The average productivity potential of high yielding thornless germplasm of water chestnut (raw fruit) at farmers field (10 t/ha) was 56.25% higher as compared to local thorny fruit bearing cultivar of water chestnut (6.4 t/ha).
- Under the study on effect of secondary and micronutrients on yield and quality of makhana it was found that foliar application of Cu proved to be 12 – 16% more effective than the soil application of Mg, Zn or B in terms of yield improvement. Combining all four nutrients with NPK led to the best yield improvement, which was 81% higher than the control and 43% higher than the sole NPK application.
- Production and reproduction performance of Dhanbadi buffalo was studied in its breeding tract. The buffalo was medium sized with jet black coloured coat. The average daily milk yield ranged from 4-10 kg per day, however, the age at sexual maturity was 3-4.5 years.
- The performance of Murrah buffaloes was found to be consistent as the total milk yield, standard lactation milk yield and average peak yield observed during the period were 2166.04±89.10, 1824.42±63.04 and 9.93±0.43 kg, respectively.
- The adult weight of ducks in Bihar, Jharkhand, Chhattisgarh, Odisha and West Bengal was recorded at 1482.70±12.45, 1573.90±19.71, 1555.40±12.73, 1597.30±29.04 and 1513.50±17.94 g, respectively. Average age of 1st laying was recorded at 191.12±1.63, 187.62±2.20, 187.62±1.58, 178.40±1.77 and 182.73±1.74 days, respectively.
- *Theileria orientalis* has 11 subtypes, out of which 2 subtypes are considered pathogenic for bovine.It was observed that two subtypes (1&3) are present in this region.
- The contents in mitochondrial genome of White Pekin, Khaki Campbell and Maithili breeds of duck were found to be 48.64, 47.60 and 46.59%, respectively.
- In an attempt, *Anabas testudineus* was cultured and bred in Biofloc system with high density (60-100 ms/m^2) with feeding rate of 2-4% body weight. Total fecundity was recorded at 380-400 nos./g after induced breeding with Wova-FH systhetic hormone.
- Fish production of 2042.49 kg/ha was recorded in pond after 7 months culture period where both cattle and goat manure was applied under integrated fish-livestock farming system.
- During the period, four Farmer Producer Organizations (FPO) have been formed to facilitate the agriculture produce. Two MoUs have been signed for large scale seed production of open pollinated varieties and grafted plants of brinjal and tomato and three entrepreneurs have been registered as Incubatees.
- During the period under report, the Institute published 113 nos. of research papers in journals of national and international repute, 26 book chapters, 02 books, 68 popular articles, 07 technical bulletins, 12 extension folders and 10 e-publication.
- Thirty seven villages of six districts of Bihar and Jharkhand were covered under *Mera Gaon Mera Gaurav*, and 2150 farmers were directly benefitted through various activities like training, demonstration, supply of quality planting materials, etc.
- Further, total of 165 training programmes, 21 Front Line Demonstration, 11 CFLDs and 14 On Farm Trials have been conducted for different stakeholders.

2. Introduction

The Eastern region comprises of plains of Assam, Bihar, Chhattisgarh, Eastern Uttar Pradesh, Jharkhand, Odisha and West Bengal, representing 21.85% of the geographical area of the country and supporting 33.62% of country's population. In spite of the natural resource endowments in terms of fertile soils, water resources and solar radiation, the productivity and per capita income of the farmers in the Eastern region is very low due to erratic climate variations, population explosion, land degradation, small and scattered land holdings, lack of quality seed and planting materials, poor extension mechanism, etc. However, the Eastern region of the country holds promise for a Second Green Revolution, which can be accomplished through holistic management of land, water, crops, biomass, horticultural, livestock, fishery and human resources. Though Eastern region is rich in natural resources, its potential could not be harnessed in terms of improving agricultural productivity, poverty alleviation and livelihood improvement.

ICAR Research Complex for Eastern Region (ICAR-RCER), Patna came into existence on the 22nd February 2001 to address diverse issues relating to land and water resources management, crop husbandry, horticulture, agroforestry, aquatic crops, fishery, livestock and poultry, agro-processing and socio-economic aspects in holistic manner for enhancing research capability and providing a backstopping for improvement in agricultural productivity and sustainability. Geographically, the Institute is located at 25°35'30" N latitude, 85°05'03" E longitude, at an altitude 52m above mean sea level.

The mandates of the Institute are:

- Strategic and adaptive research for efficient integrated management of natural resources to enhance productivity of agricultural production systems in eastern region.
- Transform low productivity-high potential eastern region into high productivity region for food, nutritional and livelihood security.
- Utilization of seasonally waterlogged and perennial water bodies for multiple uses of water.
- Promote network and consortia research in the eastern region.

The modalities to achieve the mandate are:

- To facilitate and promote coordination and dissemination of appropriate agricultural technologies through network/consortia approach involving ICAR institutes, State Agricultural Universities, and other agencies for generating location-specific agricultural production technologies through sustainable use of natural resources.
- To provide scientific leadership and to act as a center for vocational as well as advanced training to promote agricultural production technologies.
- To act as repository of available information and its dissemination on all aspects of agricultural production systems.
- To collaborate with relevant national and international agencies in liaison with state and central government departments for technology dissemination.
- To provide need based consultancy and advisory support for promoting agriculture, horticulture and livestock in the region.
- Socio-economic evaluation and impact assessment of agricultural technologies.

The complex has four divisions besides two research centres and two KVKs. The organizational setup of the complex is given in (Fig. 2.1).

Finance

Summary of budget allocation and expenditure during the financial year 2020-21 of the complex is presented below (Table 2.1).

Table 2.1. Financial allocation and expenditure during the year 2020-21 (Rs. in Lakhs)

Head of accounts	BE allocation	Actual expenditure*
Establishment Charges	2392.05	2391.95
TA	10.15	10.15
HRD	3.51	3.51
Capital	51.17	48.74
Other charges	1100.38	1078.35
Total	**3557.26**	**3532.70**

Table 2.2. Staff position

Category	Position	
	Sanctioned	Filled
Scientific*	91	70
Technical	61	53
Administrative	35	21
Skilled Supporting Staff	63	43

*including Director

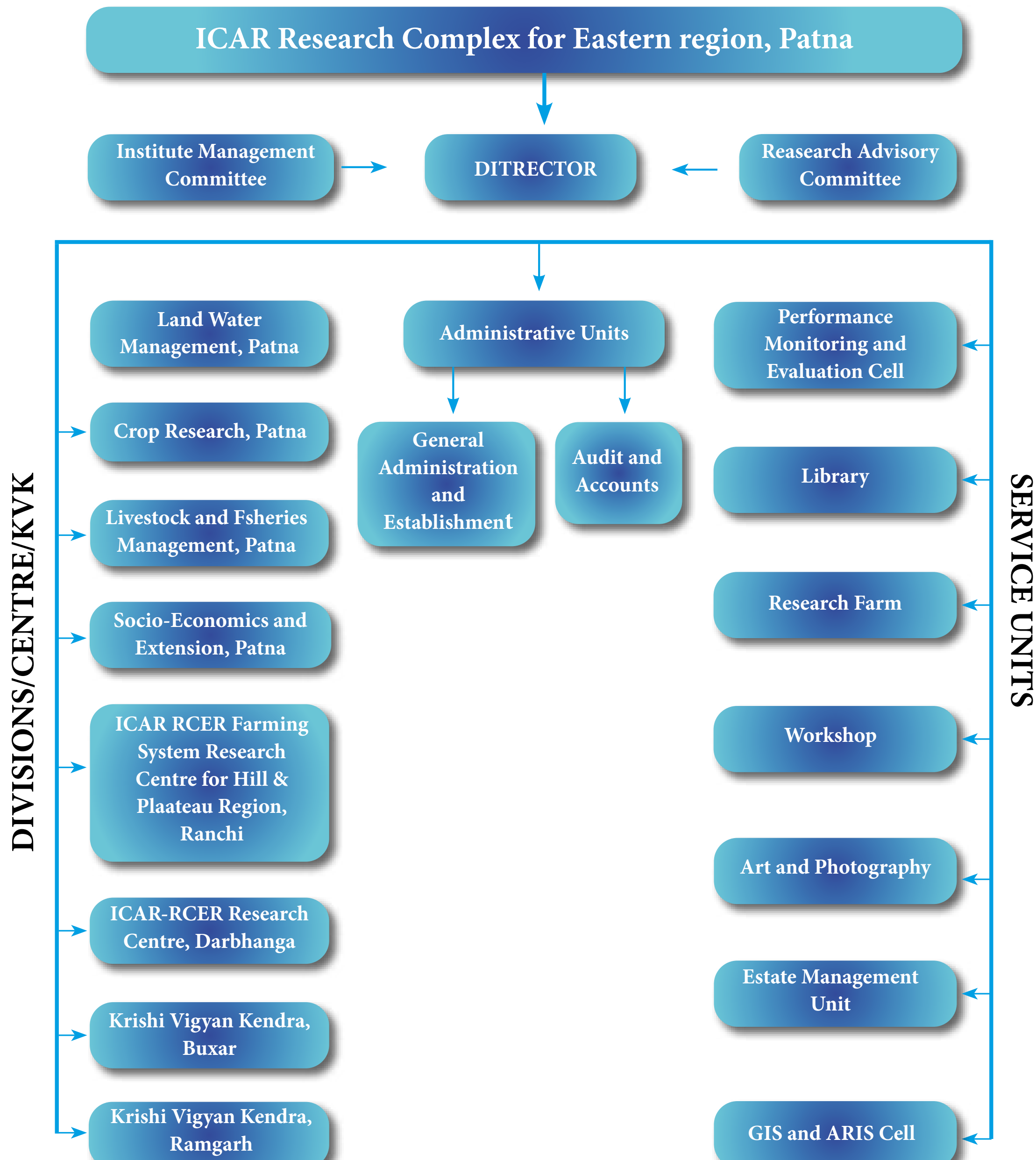


Fig. 2.1. Organogram of ICAR Research Complex for Eastern Region, Patna

3. Weather

Weather parameters *viz.* air temperature, humidity, rainfall, sunshine hours and pan evaporation were recorded at Agrometeorological Observatory of ICAR RCER, Patna. During the year it was observed that the rainfall was normal. The cumulative rainfall at the end of year was 1250.6 mm. This rainfall amount is accounted to 110.9% of long period average. The rainfall pattern and intensity over the rainfall period was erratic. The monsoon rainfall (1000.5 mm) was 105.1% of normal (951.9 mm). It was highest in the month of June (431.8 mm) and lowest in September (150.6 mm). A good amount of rainfall of 197.3 mm was also received in May (a non-monsoon month). Mean monthly maximum temperature varied from 37.6°C in April to 20.2°C in January. The April month remained warmest during 2021. Similarly, the mean monthly minimum temperature varied from 27.3°C in July to 10.3°C in January.

Further, the mean monthly relative humidity was lowest in April (44.9 %) and the highest in August (78.8 %). Highest average daily sunshine hours was recorded in the month of March (5.21 hrs/day) whereas minimum was in the month of January (0.50 hrs/day). Total open pan evaporation was 1384.4 mm, with minimum in January (47.5 mm) and maximum in July (150.2 mm). The mean wind speed reached its maximum during May (7.9 km/hr). Summary of the monthly meteorological data for the year 2021 is presented in Table 3.1. Trend in monthly variation of temperature and rainfall is presented as Fig 3.1.

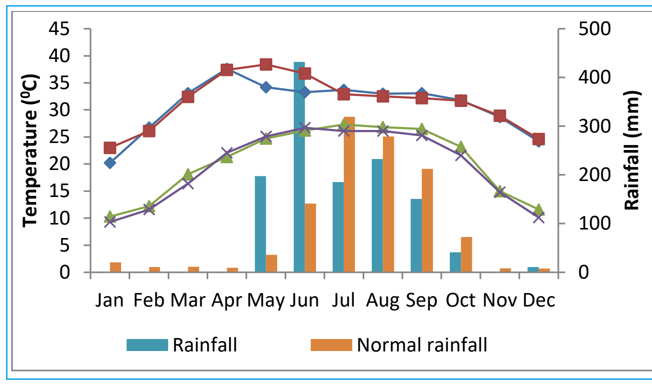


Fig. 3.1. Monthly variation of temperature and rainfall during 2021 at ICAR-RCER, Patna

Table 3.1. Mean monthly weather data of the year 2021 recorded at ICAR-RCER, Patna

Month	Temperature(°C)				Avg. RH (%)	Avg. Sunshine (hrs/day)	Total rainfall (mm)		Rainy days	Pan. Evaporation (mm)	Mean Wind Speed (Km/h)
	Max	Normal	Min	Normal			Observed	Normal			
January	20.2	23.0	10.3	9.3	72.9	0.50	0.0	20.4	0	47.5	3.1
February	26.7	26.1	12.2	11.6	62.9	2.50	0.8	11.1	0	77.0	3.0
March	33.1	32.4	18.1	16.4	51.0	5.21	0.0	11.4	0	137.5	4.1
April	37.6	37.4	21.3	22.1	44.9	4.77	0.0	9.0	0	141.9	5.6
May	34.2	38.4	24.7	25.1	64.6	3.25	197.3	35.6	7	136.9	7.9
June	33.3	36.7	26.2	26.7	75.4	2.90	431.8	141.1	13	134.7	5.7
July	33.7	32.9	27.3	26.1	76.2	2.72	185.3	319.2	9	150.2	6.6
August	33.0	32.5	26.8	26.1	78.8	2.76	232.8	279.0	13	137.5	4.7
September	33.1	32.2	26.5	25.3	76.8	4.59	150.6	212.6	11	127.3	6.5
October	31.8	31.7	23.2	21.6	74.1	4.71	41.4	72.3	4	132.8	3.8
November	28.7	28.9	15.0	14.8	63.9	3.77	0.0	8.2	0	111.6	1.6
December	24.2	24.6	11.6	10.1	68.9	1.16	10.6	7.4	2	49.5	3.0
Annual	30.8	31.4	20.3	19.6	67.5	3.2	1250.6	1127.3	59	1384.4	4.6

Extremes in weather variables for the year 2021 are reported in Table 3.2. The 17th May was the hottest day of the year with temperature 41°C while 31st January the coldest day of the year with temperature 3.5°C. The maximum amount of rainfall in a day (most rainy day) was recorded on 25th June (147.9 mm) and highest wind speed in a day was recorded on 14th September (19.36 km/hr). The highest and lowest relative humidity was observed on 25th June (91.0%) and on 4th April (25.0%), respectively. Maximum bright sunshine hours (10 hrs 38 min) was recorded on 1st September 2021.

Table. 3.2. Extremes of weather parameters observed during the year 2021

Weather events	Date	Value
Warmest day	17th May	41.0°C (Tmax)
Coldest day	31st January	3.5°C (Tmin)
Most humid day	20th June	91% (RH)
Least humid day	4th April	25% (RH)
Most rainy day	25th June	147.9 mm (Rainfall)
Most shiny day	1st September	10 hrs 38 min (BSSH)
Most windy day	14th September	19.36 km/hr (Wind speed)

Climate at FSRCHPR, Ranchi

Annual rainfall for the year 2021 was recorded at 1461.6 mm which was about 4.5% higher over normal rainfall (1398 mm). Compared to long term average (82.4%) the rainfall receipts during monsoon months (June-September) was 78.4% of the annual rainfall. During the reporting year the winter season rainfall was 185.4 mm contributing 12.7% to the total annual rainfall. Total rainfall recorded for the month of May and July was 80.5% and 49.4% in excess of long term normal average rainfall of the respective month, while it was 31.9% deficient in case of June. Comparison of monthly rainfall receipts with the monthly normal rainfall is presented in (Fig. 3.2). The average monthly relative humidity ranged from 69.1% in April to 96.9% in August. Summary of monthly climatic parameters at Ranchi is presented in (Table 3.3). December was the coldest month with mean monthly minimum temperature of 11.2°C while May was the hottest month with mean maximum temperature of 39.0°C. The lowest temperature of 5°C was recorded on 22nd December while the highest temperature of 40°C was recorded on 17thMay. The diurnal variation in temperature was close to 5.5°C during August which later increased to 19.2°C during the April month (Fig. 3.3).

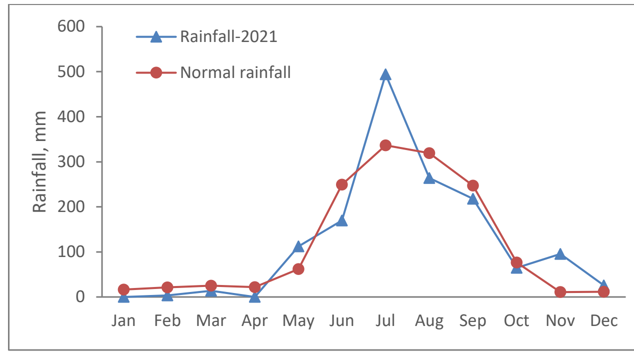


Fig. 3.2. Comparison of monthly normal rainfall with monthly rainfall of 2021

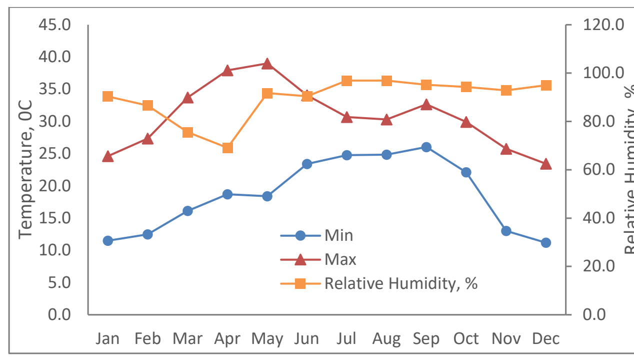


Fig. 3.3. Variations in average monthly minimum and maximum air temperature

Table 3.3. Mean monthly weather parameters at FSRCHPR, Ranchi for 2021

Month	Total Rainfall, mm		Temperature, °C		Relative Humidity, %
	Normal rainfall	Rainfall (2021)	Mini-mum	Maxi-mum	
Jan	17	0	11.5	24.6	90.3
Feb	21	3.3	12.5	27.3	86.6
Mar	25	14	16.1	33.7	75.6
Apr	22	0	15.7	37.9	69.1
May	62	112.6	18.4	39.0	91.7
Jun	249	169.9	23.4	34.1	90.4
Jul	337	494.2	24.8	30.7	96.9
Aug	319	264	24.8	30.3	96.9
Sep	247	218.18	26.0	32.6	95.2
Oct	77	64.4	22.1	29.9	94.3
Nov	11	95.4	13.0	25.8	92.8
Dec	12	25.6	11.2	23.4	95.0
Annual	1398	1461.6	18.3	30.8	89.6

4. Climate Change

Effect of Drought and Heat Stress on Wheat: Changes in Plant Physiological Traits and Yield Attributes

Twelve wheat genotypes were evaluated during rabi season of 2020-21 at experimental farm of ICAR-RCER, Patna under late sown condition (29 December, 2020) in order to study the effect of water deficit and heat stress on physiological traits and yield attributes. The maximum temperature range at the time of anthesis to grain filling for late sown crop was 27-38.4^{0}C while minimum temperature ranged between 12-23.2^{0}C (Fig. 4.1). The optimum temperature for wheat anthesis to grain filling ranges from 12 to 22 ^{0}C. The maximum temperature range at anthesis for late sown crop was higher than optimum indicating late sown crop faced heat and drought stress since rainfall during this period was only 0.8mm (Fig. 4.2). In terms of yield and yield attributes, the grain yield (kg/ha) significantly declined by 8.6 and 29.6 % from late sown control to reproductive stage drought condition. Apart from this, biological yield (BY), test weight, ear length (EL) was also declined under late sown condition in both the growing areas (Table 4.1). Physiological traits like relative water content (RWC), chlorophyll content (CHL) also showed decreasing trend from control to Relative Saturation Deficit (RSD) under late sown condition (Table 4.2). The maximum reduction in RWC (7.7%) and Chlorophyll content (20.5%) were observed under combined stress (terminal drought and heat) Biochemical traits like TBARS content (indicating lipid peroxidation) and Proline level (indicating water deficit stress) were higher under both the stress conditions, indicating the negative effect of stresses on wheat genotypes. Overall, negative effect of combined stress was more pronounced as compared to individual stress (Fig. 4.3).

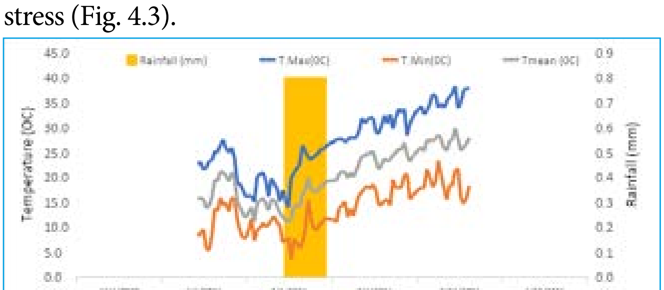


Fig. 4.1. Weather parameters during wheat growing season of 2020-21

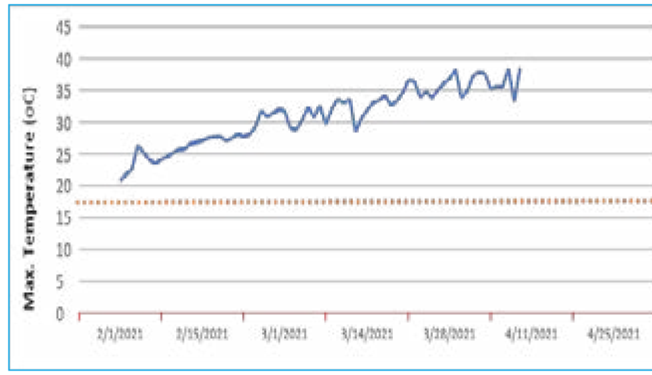


Fig. 4.2. Temperature range during anthesis to grain filling stage of wheat crop during 2020-21

Table 4.1. Effect of water deficit and heat stress on yield and yield attributes of wheat genotypes grown under different experimental conditions

Parameters	LS-C	LS-VSD	LS-RSD	% Reduction from C to VSD	% Reduction from C to RSD
GY (t/ha)	4.52	4.13	3.18	8.63	29.65
BY (t/ha)	10.27	9.18	7.40	10.67	28.01
TGW (g)	42.14	39.90	37.50	5.32	11.01
EL (cm)	10.05	9.70	9.63	3.48	4.15
Tiller/m^2	612	580	541	5.23	11.60
HI (%)	43.60	40.40	39.10	7.34	10.32
LSD (0.05); Grain Yield (GY): 0.075; Biological Yield (BY): 0.82; Thousand Grain Weight (TGW):0.31; Tiller/m^2: 71.62; Ear Length (EL): 0.88 ; Harvest Index (HI): 5.94					

Table 4.2. Effect of water deficit and heat stress on physiological parameters of wheat genotypes grown under different experimental conditions

Parameters	LS-C	LS VSD	LS RSD
RWC (%)	82.1	80.2	76.2
CHL (mg/g)	2.76	2.69	2.29
TBARS (N mol/g)	67.4	82.5	95.5
PROLINE (mg/g)	3.7	4.6	6.2
FLL (cm)	28.70	26.7	25.36
FLW (cm)	1.82	1.73	1.64
FLL: Flag Leaf Length; FLW: Flag Leaf Width			

Fig. 4.3. Field view of experimental farm during *rabi* 2020-21

Comparative Field Efficacy of Chemical Insecticides Against Chilli Thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae)

A field experiment was conducted to find out the effective chemical molecules for managing the chilli thrips, Scirtothrips dorsalis and their effects on coccinellid predators at ICAR-RCER, FSRCHPR, Ranchi. Efficacy of the insecticides was determined by comparing the number of insects, immature and adult of natural enemies, and marketable yield in insecticide treated versus untreated control plots. Spray of Spinosad 45SC @ 70 g a.i. ha^{-1}, Emamectin benzoate 5SG @ 11 g a.i. ha^{-1}, Imidacloprid 200SL @ 40 g a.i. ha^{-1} and fipronil 5SC @ 30 g a.i. ha^{-1} was the most effective against S. dorsalis in chilli. Application of Fenpropathrin 30EC @ 75 g a.i. ha^{-1} followed by Imidacloprid and Thiacloprid 240SC @ 40 g a.i. ha^{-1} were found moderately adverse and Spinosad and Emmamectin benzoate were safer to coccinellids predators (Fig. 4.4). Study based on principal component analysis (PCA) suggested that Spinosad, Emamectin benzoate, Fipronil and Imidacloprid can be recommended to manage S. dorsalis on rotational basis in the chilli ecosystem.

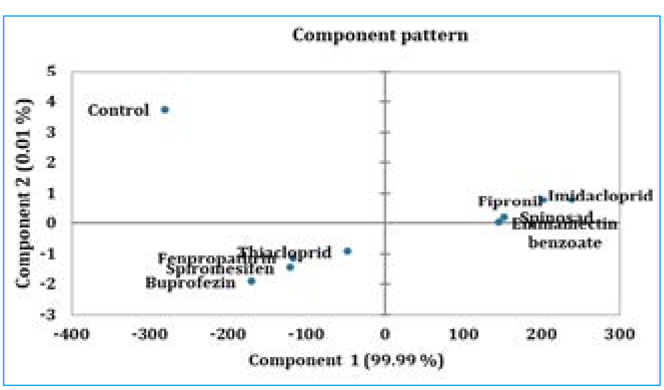


Fig. 4.4. Plot of principal component analysis based on mean population of thrips after application of treatments, coccinelid and marketable yield among the insecticidal treatments

Simulating Production Potential of Rice and Wheat Under Changing Climate over Bihar

Rice variety Swarna Shreya was transplanted during Kharif 2020 at 15 days interval on three different dates (20 July, 05 August and 20 August) along with three irrigation levels. A Pani pipe was installed in every plot and soil moisture depletion was calculated using the Pani pipe concept and total quantity of irrigation water was also calculated as and when the water was applied in the plots along with the rainfall received in the region. Grain yield of rice was reduced by 14 % with delayed transplanting of 15 days and further by 23% (another 15 days delay) as compared to the yield of rice transplanted on July 20, 2020 (5.2 t/ha). Significant effect of irrigation treatment was also found during this year. Application of 5 cm irrigation water after disappearance of irrigation water (I1) produced 5.0 t/ha paddy yield. While second irrigation treatment (I2) reported 10% of yield reduction whereas I3 reported 33% of yield reduction compared to normal irrigation practice (Table 4.3).

Similarly, Wheat variety HD-2967 was sown during rabi season of 2020-21 with similar treatment combinations of date of sowing at 15 days interval (9 November, 24 November and 9 December 2020) with three sets of irrigation treatments. Irrigation was applied in the crop fields on critical growth stages of wheat crop (Irrigation at 5 stages i.e. CRI+Maximum tillering+Booting+Milk+Dough -1_1, Irrigation at 3 stages i.e. CRI+Booting+Milk-1_2 and Irrigation at 2 stages i.e. CRI+Booting-1_3). Wheat crop sown on D1 reported highest grain yield of 5.0 t/ha which was reduced by 18% due to 15 days delayed sowing (24 Nov. 2020) and further by 26% due to 30 days delayed sowing (9 Dec 2020) as compared to wheat sown on 9 November 2020. Effect of delay in sowing was clearly evidenced in terms of heat use efficiency with similar pattern of reduced value as sowing date progressed beyond November 9 (Table 4.3). The yield of wheat crop receiving 3 and 2 irrigations reduced by 16 and 23 per cent, respectively as compared to normal irrigation practice (4.9 t/ha). In case of water saving I2 with three levels of irrigation consumed 16 % less water and I3 with two levels of irrigation consumed 23 % less water as compared to I1 i.e. five levels of irrigation (consumed 4.9 m^3 volume of irrigation water per plot)

Table 4.3. Effect of sowing dates and irrigation level on rice and wheat

Treatment	Grain yield (t/ha)	Heat Use Efficiency (kg/ha°C days)	Crop Water Productivity (kg/m³)
Rice			
I1	5.1	2.0	0.7
I2	4.4	2.0	0.6
I3	3.9	1.8	0.6
CD at 5%	0.62	NS	NS
D1 (20 July)	5.2	2.4	0.6
D2 (5 Aug)	4.7	1.8	0.6
D3 (20 Aug)	3.5	1.6	0.7
CD at 5%	0.62	0.43	NS
Wheat			
I1	4.9	2.5	1.9
I2	4.1	2.1	2.5
I3	3.8	1.9	3.5
CD at 5%	0.87	0.44	0.72
D1	5.0	2.6	3.3
D2	4.1	2.1	2.6
D3	3.7	1.9	2.0
CD at 5%	0.87	0.44	0.72

5. Cereals

Rice

Evaluation and Identification of Rice Genotypes for Tolerance to Reproductive Stage Drought

Forty-eight rice genotypes were evaluated under reproductive stage drought stress and non-stress (irrigated) conditions during Kharif 2021. Grain yield varied from 5.11 to 7.21 t/ha and 3.35 to 5.98 t/ha under non-stress and drought stress conditions, respectively. Irrespective of genotypes, drought stress at reproductive stage caused significant reduction in plant height (29.1%), tillers (20.9%), panicle length (20.0%), grain yield (16.8 %) and biological yield (25.9%); however, the responses varied among genotypes. Among rice genotypes, IR 108199-24-32-1-1-B (5.98 t/ha), IR 107891-B-B-1023-1-1 (5.95 t/ha), IR 107891-B-B-1432-2-1 (5.93 t/ha), IR 107891-B-B-111-2-1 (5.92 t/ha), IR 106312-50-1-1-1 (5.87 t/ha), IR 107891-B-B-1253-1-1 (5.70 t/ha), IR14L362 (5.70 t/ha) and IR14L157 (5.68 t/ha), IR 93827-29-1-1-4 (5.56 t/ha), IR14L613 (5.52 t/ha), IR 93827-29-2-1-3 (5.52 t/ha) and IR14L155 (5.50 t/ha) showed better drought tolerance at reproductive stage as compared to check varieties Sahbhagi Dhan (4.43 t/ha) and IR64 (3.35 t/ha).

Evaluation of Rice Genotypes for Tolerance to Multiple Stresses (Submergence and Drought)

Twenty-four rice genotypes were evaluated under control (non-stress), drought, submergence, and combine stress (submergence + drought) conditions during Kharif 2021. The control trial was maintained by applying irrigation as and when required. Under the submergence experiment, after ten days of transplanting the crop was completely submerged. The crop was kept submerged under 1.0 to 1.25 m water depth for fifteen days and thereafter water was drained out from the plot. Under drought stress experiment, crop faced stress at the reproductive stage. Under combined stress crop faced 15 days submergence at vegetative stage and later drought at the reproductive stage. The average grain yields of 6.01, 2.35, 1.54 and 0.886 t/ha were recorded under non-stress, drought, submergence and combine stress condition, respectively. Results of the present study revealed that irrespective of the genotypes, there was a significant reduction in grain yield of rice under drought (60.9%), submergence (74.3 %) and combine stress (85.2%) condition compared to non-stress. Among rice genotypes, IR 102796-14-77-2-1-2 (1.52 t/ha), IR 96321-558-563-B-2-1-1 (1.40 t/ha), IR 102777-18-64-1-2-6 (1.37 t/ha), IR 96321-315-294-B-1-1-1 (1.31 t/ha), RCPR 10 (1.25 t/ha), IR 96321-315-323-B-3-1-3 (1.18 t/ha), IR 96321-558-209-B-6-1-1 (1.18 t/ha), and IR 96321-558-563-B-2-1-3 (1.14 t/ha) have been found promising for multiple stresses (Submergence + drought) tolerance as compared to check varieties Swarna Sub 1 (0.870 t/ha) and IR64 Sub 1 (0.760 t/ha). Grain yield of different rice genotypes varied from 1.36-4.09 t/ha, 0.800-2.60 t/ha, 0.200-1.52 t/ha and 4.46-7.116 t/ha under drought, submergence, combine stress and non-stress conditions, respectively. Further, higher spikelet fertility percentage (53.5-63.6%) was recorded in identified promising genotypes as compared to check varieties (34.8-46.3%) under multiple stresses conditions.

Resource Remobilization during Grain Filling under Drought

A field drought- screening was done during *kharif* season 2021 with the aim to identify drought tolerant genotypes having high harvest index and mobilization efficiency. Thirty-six rice genotypes comprised of twenty-five advanced breeding lines and eleven high yielding varieties were evaluated under two condition i.e. stress (reproductive stage drought) and non-stress (irrigated) conditions (Fig. 5.1). Under drought stress experimental field, the crop was grown under normal irrigation for four weeks after transplanting and then irrigation was withdrawn, and no further irrigation was applied to stress field. Under the present study, rice genotypes having high harvest index (HI) with good grain yield under drought conditions have been identified. The average grain yield of 2.40 and 3.39 t/ha was observed under drought and control condition, respectively. Finding showed that irrespective of genotypes, drought stress (reproductive stage) caused significant reduction in grain yield (29.18%) and biological yield (21.67%); however, the responses varied among genotypes. Under drought condition, highest grain yield was recorded in IR 134118-4-B-RGA-B-RGA-B-RGA-17 (3.54 t/ha, 39.0%) followed by IR 134116-5-B RGA-B RGA-B RGA-

32 (3.049 t/ha, 42.0%), Swarna Shakti Dhan (3.038 t/ha, 42.9%), IR 134117-2-B-RGA-B-RGA-B-RGA-14 (2.918 t/ha, 33.9%), DRR Dhan 42 (2.848 t/ha, 39.0%), Swarna Shreya (2.764 t/ha, 41.9%), DRR Dhan 54 (2.749 t/ha, 38.9%) and IR 134117-2-B-RGA-B-RGA-B-RGA-30 (2.708 t/ha, 38.8%). They also showed better harvest index as well as drought tolerance at reproductive stage as compared to check varieties IR64 (1.635 t/ha), and Sahbhagi Dhan (2.66 t/ha). Further, resources remobilization efficiency (%) of assimilates was highest in rice genotype DRR Dhan 42 (42.06%) followed by IR 134116-5-B RGA-B RGA-B RGA-32 (32.65%) and IR 134117-2-B-RGA-B-RGA-B-RGA-30 (30.9%) as compared to check varieties IR64 (4.67%), and Sahbhagi Dhan (7.12%) under drought condition.

Evaluation of Rice Genotypes for Submergence Tolerance

Twenty rice genotypes along with Swarna Sub 1, IR 64 Sub1 and Sambha Mahsuri Sub 1 as tolerant and Swarna as susceptible checks were evaluated for submergence tolerance during kharif 2021 (Fig. 5.2). After eleven days of transplanting, the crop was completely submerged for 21 days with 1.0 to 1.25 m water depth and thereafter water was drained out of the field. Burt due to natural rainfall, the crop was again submerged for next seven days. The maximum survival percentage was recorded in IR 102796-14-77-2-1-2 (16%), followed by IR 96321-558-563-B-2-1-1 (10%) and IR 102777-18-64-1-2-6 (9%). Rice genotypes IR 102796-14-77-2-1-2 (0.797 t/ha), IR 96321-558-563-B-2-1-1 (0.446 t/ha), IR 102777-18-64-1-2-6 (0.29 t/ha), and IR 96321-315-294-B-1-1-1 (0.18 t/ha) performed better as compared to Swarna Sub 1 (0.11 t/ha), IR 64 Sub1 (0.108 t/ha), Sambha Mahsuri Sub 1 (0.06 t/ha). Further, higher spikelet fertility percentage (61-70%) was recorded in identified promising genotypes as compared to check varieties (51-55%). The lowest (30%) spikelet sterility was recorded in IR 102796-14-77-2-1-2 followed by IR 102777-18-64-1-2-6 (32%).

Evaluation and Identification of Rice Genotypes for Multi-Stages Drought Tolerance

Thirty-two rice genotypes were evaluated under multi-stages drought (MSD), reproductive stage drought (RSD), vegetative stage drought (VSD), seedling stage drought (SSD) stress and non-stress (irrigated) conditions during *kharif* 2021. In MSD experimental field, water was provided only once on the day immediately after sowing so that the seeds can properly germinate. In RSD, VSD and SSD experimental field, drought stress was imposed at respective stages by withholding irrigation and withdrawing water from the stress field. Grain yield of different genotypes was varied from 0.44 to 2.78 t/ha, 1.81 to 3.44 t/ha, 2.91 to 5.05 t/ha, 3.58 to 5.655 t/ha and 4.60 to 6.85 under, MSD, SSD, RSD, VSD and non-stress conditions, respectively. Results of the study revealed that irrespective of the genotypes, there was a significant reduction in mean grain yield under MSD (61.1%), SSD (49.30%), RSD (24.45%) and VSD (14.9%) stresses as compare non-stress condition. Among

Fig. 5.1. Evaluation of rice genotypes under drought and control conditions.

Fig. 5.2. Evaluation of rice genotypes under submergence condition.

rice genotypes; IR 84899-B-183-20-1-1-1(2.78 t/ha), IR93827-29-2-1-1-3 (2.74 t/ha), IR93827-29-1-1-2 (2.66 t/ha), IR 93827-29-1-1-3 (2.65 t/ha), IR 84899-B-179-13-1-1-1 (2.63 t/ha), IR83929-B-B-291-2-1-1-2 (2.62 t/ha), IR84899-B-182-3-1-1-2 (2.55 t/ha), IR93827-29-1-1-4 (2.54 t/ha), IR93810-17-1-2-3 (2.53 t/ha), IR 14 L 362 (2.47 t/ha), IR 95786-9-2-1-2 (2.41 t/ha) and IR 95817-5-1-1-2 (2.34 t/ha) were identified promising for multi-stages drought tolerance compare to Sahbhagi Dhan (1.62 t/ha).

Response of Drought Tolerant Rice Cultivars to Iron and Zinc

A field experiment was conducted during *Kharif* 2021 under the ICAR Window 3 Project (ICAR-IRRI collaborative project) to study the response of Nano-N and Nano-Zinc on crop growth, phenology, nutrient

Fig. 5.3. Evaluation of nano-fertilizer for iron and zinc fortification

use efficiency, yield, and grain quality traits (Fig. 5.3). Nano-N, Nano-Zinc and ferrous sulphate were sprayed at the Panicle Initiation (PI) stage. Treatments with Nano-Zn (4 ml/l), Nano-N (4 ml/l), and combined application of Nano-Zn and Nano-N (4 ml/l doses of each fertilizer) produced 6.26, 6.21, and 6.37 t/ha grain yield which is 4.16, 3.32 and 5.99% higher than recommended dose of fertilizers (RDF; 6.01 t/ha).

Release and Notification of Rice Variety Swarna Unnat Dhan

A high yielding multiple stress tolerant rice variety Swarna Unnat Dhan (IET 27892) has been developed by ICAR Research Complex for Eastern Region, Patna, Bihar (Fig. 5.4). It has been released and notified for cultivation under irrigated transplanted condition in the states of Bihar, Odisha, West Bengal, Madhya Pradesh and Maharashtra of India. Swarna Unnat Dhan is an early duration (115-120 days), semi-dwarf, high yielding (5.0-5.5 t/ha), multiple stress (drought, disease and insect pest) tolerant, lodging resistant with desirable cooking quality traits and having long slender grain

Fig. 5.4. Production of Swarna Unnat Dhan

type. Swarna Unnat Dhan is suitable for cultivation under transplanted condition in irrigated as well as water scarcity areas. Quality wise, Swarna Unnat Dhan possesses 77.7% hulling, 67.4% milling, 63.2 % head rice recovery (HRR) with desirable intermediate alkali spreading value, amylose content (24.34%) with long slender grain type. Rice variety Swarna Unnat Dhan showed moderate resistance to bacterial leaf blight, false smut, sheath rot, leaf blast and brown spot diseases and major pests like stem borer, BPH and gallmidge under natural condition.

Release and Notification of Rice Variety Swarna Sukha Dhan

A high yielding multiple stress tolerant rice variety Swarna Sukha Dhan (IET 24692) has been developed by ICAR Research Complex for Eastern Region, Patna, Bihar (Fig. 5.5). It has been released by State Seed Sub-Committee (Uttar Pradesh) and notified by Govt. of India for cultivation under direct seeded condition in drought prone rainfed areas of Uttar Pradesh. Swarna Sukha

Fig. 5.5. Production of Swarna Sukha Dhan

Dhan is an early duration (110-115 days), semi-dwarf, high yielding (3.5-4.0 t/ha), multiple stress (drought, disease and insect pest) tolerant, with desirable quality traits and high micronutrient (Zinc:23.1 ppm)content. It also possesses desirable cooking quality traits and having medium slender grain type. Swarna Sukha Dhan is suitable for cultivation under direct seeded condition in rainfed midland to upland ecosystem of Uttar Pradesh. Quality wise, Swarna Sukha Dhan possesses 78.4% hulling, 70.9% milling, 68.4 % head rice recovery with desirable intermediate alkali spreading value (ASV=4.0), amylose content (22.32%) with medium slender grain type. Rice variety Swarna Sukha Dhan was found moderately resistant to BLB, false smut, leaf blast, sheath blight, RTD and brown spot diseases and major pests like stem borer, leaf folder, whorl maggot, and BPH under natural condition.

Nomination and Promotion of Rice Entries and Trials Conducted under AICRIP Programme

On the basis of performance under on-station trials, seven promising advance breeding lines (RCPR 79, RCPR 80, RCPR 81, RCPR 82, RCPR 83, RCPR 84 and RCPR 85) of rice have been nominated (under different trials/ecology) to AICRIP for multi-locational testing/evaluation during *kharif* 2021. Moreover, five rice genotypes RCPR 61 (IET 28378), RCPR 68 (IET 29036), RCPR 70 (IET 29405), RCPR 71 (IET 29427) and RCPR 75 (IET 29243) have been promoted from IVT to AVT 1 trial after first year testing during *Kharif* 2020 under AICRIP programme. Rice genotype RCPR 60 (IET 28329), has been promoted from AVT 1-E-TP to AVT 2-E-TP and RCPR 63 (IET 28631) from AVT 1-Aerobic to AVT 2-Aerobic trial after second year testing. During *kharif* 2021, five hundred and two rice genotypes (comprising of advanced breeding lines and check varieties) belonging to thirteen AICRIP trials (AVT 2-E-TP, AVT 1-E-TP, IVT-E-TP, AVT 1-IME, IVT-IME, AVT 1-IM, IVT-IM, AVT 1-Late, IVT-Late, IVT-aerobic, AVT-1-aerobic, AVT 1 NIL-Late and AVT 1-NIL- IM & IME) were conducted at ICAR RCER, Patna. Evaluation of AICRIP trials were conduct at regular interval by monitoring team.

Maintenance and Generation Advancement of Rice Breeding Materials

One hundred ten rice genotypes comprising of advanced breeding lines and released varieties of different duration were grown, purified and maintained in rice cafeteria during kharif 2021 at ICAR RCER, Patna. Besides, five F_4, nine F_5, seven F_7 generation rice breeding materials along with parents were also raised. Uniform plants or lines of early and medium early duration have been selected based on the plant type, panicle length, effective tiller numbers, grain features, lodging resistance and diseases and insect pests tolerance. The seeds of rice breeding materials have been retained for further evaluation and generation advancement.

Collection of Rice Landraces in Flood-Plains of Eastern India

A total of 87 accessions of traditional lowland rice germplasm consisting of *sali dhan* (aman rice), *joha dhan* (short grain aromatic rice), *bora dhan* (soft rice) and *bao dhan* (deepwater rice) were collected from flood prone ecosystem under Azad, Panigaon and Nowboicha blocks in North Lakhimpur district and Silapathar and Machhkhowa blocks of Dhemaji districts of Assam. Area is located in the southern border of Arunachal Pradesh along the Himmalayas. Rice fields in these areas are chronically flood affected. The depth and duration of flooding vary from year to year. In deep water areas, traditional bao dhan is grown which has the ability of stem elongation with the rising water level. These are very long duration crop, grown from February-March to November-December. In semi-deep to medium land, traditional *Sali, joha and bora dhan* are grown in these districts. Area under modern rice varieties was very less.

Evaluation of Traditional Rice Landraces in Flood-Plains of Eastern India

Seventeen traditional lowland rice germplasm (*agahnidhan*) from Bihar collection along with three improved varieties of lowland rice (Rajendra Mahsuri, Rajshree and Varsadhan) were evaluated during 2021 *kharif* for agro-morphological characters (Table 5.1). All of these traditional germplasm are very tall (about 2 m in height), long duration (about 160 days) and low yielder. Grain yield ranged from 1.32 t/ha for Jaswa-2 to 3.38 t/ha for Ramdulari-2. Accessions with fine grain quality like Sataria, Phul Jaswa and Palia may be used for improvement of grain quality in breeding programme.

Evaluation of Traditional Short Grain Aromatic Rice of Eastern India

Thirty eight traditional aromatic short grain rice germplasm were evaluated for agro-morphological traits during *kharif* 2021 along with four improved aromatic rice varieties Bauna Kalanamak, Pusa Basmati 1176, Ketekijoha and CR Dhan 909. Improved varieties were semi-dwarf to semi-tall in plant height whereas

Table. 5.1. Performance of traditional lowland rice germplasm

Genotypes	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Tillers / hill	Grains/ panicle	1000-grain weight (g)	Harvest index (%)	Grain yield (t/ha)
Barchha	127	198.5	27.6	12.1	102	27.9	18.0	2.36
Dhusari	129	221.4	27.9	12.9	86	23.3	15.2	2.04
Harinkel	131	197.1	29.3	14.1	134	21.5	13.8	1.82
Samayadhan	132	186.3	30.3	12.4	121	20.5	13.7	1.56
Jaswa-1	131	183.1	29.5	14.8	109	26.0	17.4	2.09
Jaswa-2	129	179.5	30.3	13.5	96	22.7	8.9	1.32
Kusumser	132	206.9	29.7	15.0	109	22.9	20.1	2.94
Laxman Bhog	129	188.1	29.8	13.1	122	17.6	16.0	2.47
Palia	128	202.8	30.3	14.1	129	15.6	10.4	1.48
Panjhali	128	199.8	26.3	14.3	118	22.9	18.1	2.52
Parwa Pankh	127	150.3	29.2	14.1	79	22.2	13.7	1.50
Phul Jaswa	128	185.5	30.1	14.5	107	15.9	17.0	2.48
Ramdulari-1	128	193.3	26.5	13.5	137	18.1	18.9	2.34
Ramdulari-2	128	186.5	27.5	13.1	156	18.0	26.0	3.38
Sataria	133	194.8	24.9	13.2	127	16.1	17.3	1.97
Ujla Dhusari	133	201.3	26.9	13.5	89	23.8	19.3	2.71
Vaidehi	132	185.1	26.5	15.6	101	23.8	14.8	1.92
Rajendra Mahsuri	119	134.1	27.0	14.0	102	17.8	27.2	3.83
Rajshree	113	162.2	28.7	13.8	120	17.6	20.5	2.69
Varsadhan	128	166.2	27.2	15.1	107	22.8	21.6	2.57
SEM	0.3	2.3	0.3	0.8	5.5	0.2	1.6	0.20

traditional germplasm were very tall (ranged from 1.62- 2.15m). Severe crop lodging was observed in all the traditional genotypes and hence the grain yield was very low. It ranged from 0.91 t/ha for Blackrice-2 to 2.38 t/ha in Chandanchur-2). The traditional short grain aromatic rice varieties are grown by farmers in eastern India for their excellent grain quality and aroma despite poor grain yield.

Evaluation of Elite Rice Genotypes Suitable for Favourable Shallow Lowland

Nine elite rice genotypes were evaluated during 2021 *kharif* under irrigated condition along with Naveen, Rajendra Sweta and Swarna as check varieties. Performance of these genotypes is presented in Table 5.2. Swarna was the best check with grain yield of 6.85 t/ha. Among the test entries TP 30191 was the highest yielder (6.89 t/ha). Its yield was at par with Swarna but matured 13 days earlier than Swarna and can be served as a substitute for Swarna. The genotypes like RP5535-8 (6.63 t/ha), RP5535-22 (6.51 t/ha) and RP5423-62 (6.25 t/ha) have more per day productivity than Swarna by virtue of their shorter crop duration.

Evaluation of Elite Rice Genotypes Suitable for Mid-Early Duration

Rice variety of mid early duration i.e.120-130 days fits well in the rice-wheat system of Indo-Gangetic plain. Therefore, 10 elite rice genotypes of mid-early maturity were evaluated along with IR64 sub-1 and Swarna sub-1 as check during 2021 kharif. Performance of the genotypes is presented in Table 5.3. As Swarna sub-1 is of longer duration (113 days to 50% flowering), therefore IR64 sub-1 is the appropriate check for comparison. Among the test entries CR Dhan203 (5.85 t/ha)), CR Dhan 309 (5.60 t/ha) and IR11F 195 (5.51 t/ha) were the top three entries producing significantly higher grain yield than IR64 sub-1

Evaluation of Rice Genotypes for Submergence Tolerance

Eleven rice genotypes were evaluated for submergence tolerance alongwith Swrana as susceptible check and Ciherang sub1, IR64 sub1, Savitri sub1, Samba Mahsuri sub1 and Swarna sub1 as tolerant check during *kharif* 2021. Thirty days old seedling was used to transplant the crop and after eleven days of transplanting

Table. 5.2. Performance of rice genotypes under favourable shallow lowland

Genotypes	Days to 50% flowering	Plant height (cm)	Ear bearing tillers/ m^2	Panicle length (cm)	Grains/ panicle (No)	Spikelet fertility (%)	1000-grain weight (g)	Harvest index (%)	Grain yield (t/ ha)
RP5484-6	99	132.1	385	24.4	151	75.1	20.8	42.9	5.92
RP5535-8	101	135.9	378	25.5	181	80.4	21.8	39.0	6.63
RP5366-13	95	139.3	405	25.2	120	80.0	24.0	42.0	6.33
RP5535-22	96	130.4	407	26.9	126	82.8	23.2	47.7	6.51
RP5410-27	94	124.0	431	24.9	224	81.7	15.6	23.1	3.33
RP5537-42	98	134.3	510	26.5	169	82.7	14.6	42.7	5.97
RP5423-62	88	118.0	378	26.6	187	71.4	13.7	41.9	6.25
RP5528-85	98	140.9	444	25.3	158	66.5	16.6	35.3	5.64
TP 30191	101	115.7	477	24.3	182	84.7	18.8	46.4	6.89
Naveen	88	135.5	458	29.1	150	77.1	16.8	42.6	5.31
Rajendra Sweta	117	118.9	408	22.7	161	73.3	14.4	35.4	5.13
Swarna	114	109.6	427	23.5	108	66.6	18.1	41.1	6.85
SEM	0.8	2.5	18.7	0.5	11.9	3.1	0.3	2.2	0.30

Table 5.3. Performance of mid-early duration rice genotypes under favourable condition

Genotypes	Days to 50% flowering	Plant height (cm)	Ear bearing tillers/ m^2	Panicle length (cm	Grains/ panicle (No)	Spikelet fertility (%)	1000-grain weight (g)	Harvest index (%)	Grain yield (t/ ha)
CR Dhan201	89	131	398	29.2	86	56.5	22.7	35.2	4.45
CR Dhan203	86	120	431	26.1	122	71.7	20.6	48.9	5.85
CR Dhan204	88	141	455	29.0	154	77.9	17.4	46.3	5.33
CR Dhan206	87	142	491	29.0	154	75.2	18.5	38.8	4.81
CR Dhan210	91	135	370	29.0	133	71.3	22.3	38.8	5.11
CR Dhan 309	87	127	372	26.4	139	80.2	22.3	41.6	5.60
IR09L 342	87	130	411	26.5	151	74.2	19.9	38.6	5.13
IR10F 365	89	137	418	29.5	155	75.7	19.6	39.1	4.97
IR11F 195	89	132	387	27.2	140	71.4	20.0	40.6	5.51
TP30193-1	90	132	438	28.9	112	75.8	22.8	42.7	5.27
IR64 sub1	82	116	429	27.3	102	68.6	24.7	40.5	5.03
Swarna sub1	113	124	440	26.7	173	78.9	16.8	48.3	6.76
SEM	0.88	1.6	16.6	0.5	6.0	2.6	0.2	1.6	0.22

the crop was completely submerged for 20 days. After 20 days the water could not be be drained out due to incessant rain during the period of draining out. As such the crop remained submerged for 27 days without any break. This laid to the severe mortality even in the submergence tolerant varieties (Table 5.4).

Evaluation of Nano Diammonium Phosphate (DAP) Fertilizer on the Performance and Yield of Rice and Wheat Crops

A field experiment with rice cultivar *Swarna Shreya* was carried out during *kharif*-2021 to evaluate the efficacy of Nano DAP fertilizer on crop growth and grain yield (Fig. 5.6). The study included ten treatments, T_1: 0% P & 0% Basal N (no Basal DAP); 100% N & K (control); T_2: 100 % NPK; T_3: 75 % DAP and 100 % N & K; T_4: 50 % DAP and 100 % N & K (recommended); T_5: T_3 + ST/ SD with Nano DAP @ 5 ml / kg seed for ST + FS with Nano

Fig. 5.6. Evaluation of nano-DAP fertilizers

Table 5.4. Survival % in different rice genotypes during 27 days of submergence (*kharif* 2021)

Genotypes	Survival %
IR09L337	5.2
IR09L342	8.0
IR10L 182	5.7
IR11F 195	14.5
TP 30191	7.3
TP 30193	8.2
TP 30499	0.6
TP 30504	0.8
TP30193-1	0.0
TP30193-2	1.1
Swarna	0.9
Ciherang sub1	3.9
IR64 sub1	1.0
Savitri sub1	0.6
Samba Mahsuri sub1	1.2
Swarna sub1	1.9

DAP @ 2 ml/ l of water at 20-25 DAT; T_6: T_3 + ST/SD with Nano DAP @ 5 ml / kg Seed for ST + FS with Nano DAP @ 4 ml/ l of water at 20-25 DAT; T_7: T_4 + ST/SD with Nano DAP @ 5 ml / kg Seed for ST or 5 ml/ l water for SD + FS with Nano DAP @ 2 ml/l of water at 20-25 DAT; T_8: T_4 + ST/SD with Nano DAP @ 5 ml / kg seed for ST + FS with Nano DAP @ 4 ml/ l of water at 20-25 DAT; T9: T4 + ST/SD with Nano DAP @ 5 ml / kg seed for ST + first FS with Nano DAP @ 2 ml/ l of water at 20-25 DAT and second spray- before one week of flowering stage or 45 days after seed germination/transplanting; T_{10}: T_4 + ST/SD with Nano DAP @ 5 ml / kg seed for ST + first FS with Nano DAP @ 4 ml/ l of water at 20-25 DAT and second spray- before one week of flowering stage or 45 days after seed germination/transplanting. All variants including control were performed in triplicate following RCBD method. At the stage of grain maturity, growth and yield parameters were estimated as given in Table 5.5.

Spray of Nano-DAP fertilizer enhanced plant height, no. of filled grains, test weight and panicle length, which resulted in higher production compared to control and equivalent conventional fertilizer @ 100% RDF. The highest grain yield achieved with significant superiority by using two foliar spray of nano DAP @ 4 ml/l (T_{10}) and 2 ml/l (T_9), was 6.04 t/ha and 5.9 t/ha, respectively.

Note: ST: Seed Treatment; SD: Seedling Dipping; FS: Foliar Spray; DAG - Days after Germination; DAT -Days after Transplanting.

Weed Seed Bank Dynamics, Resource-Use Efficiency and Greenhouse Gas Footprint Under Diverse Tillage Production Systems in Eastern Indo-Gangetic Plains

A field study was initiated during *kharif*, 2021 to identify an effective weed management strategy as well as a climate resilient tillage and crop establishment method

Table 5.5. Yield parameters of rice as influenced by application of nano-DAP fertilizer

Treatments	Biological yield t/ha	Grain yield t/ha	Straw yield t/ha	Harvest index (HI) %	Test weight (g)	Total no. of grains/ panicle	No. of chaffy grain/ Panicle	No. of filled grain/ panicle	No. of panicles per plant	Length of panicles (cm)	Plant height (cm)
T1	12.80	4.16	8.64	33.25	23.45	144.5	31.0	113.5	9.50	21 .00	139.26
T2	12.85	5.75	7.10	45.18	24.62	166.0	40.5	125.5	11.75	24.50	145.43
T3	13.00	5.54	7.46	41.59	24.92	160.0	39.0	121.0	11.00	22.40	143.91
T4	13.4	5.39	8.08	39.50	23.61	154.5	37.5	117.0	11.75	24.45	146.18
T5	13.22	5.54	7.68	42.24	24.31	162.0	33.5	128.5	11.00	25.55	146.19
T6	13.58	5.93	7.65	42.99	24.98	163.0	45.5	117.5	12.62	24.15	146.84
T7	13.31	4.81	8.50	36.45	24.49	151.5	40.0	111.5	10.50	24.10	147.21
T8	13.10	5.75	7.34	43.37	24.78	157.5	32.0	125.5	9.50	26.05	141.78
T9	12.86	5.86	7.00	46.06	26.05	171.0	44.5	126.5	11.25	25.00	148.50
T10	13.56	6.04	7.52	44.65	23.62	173.5	35.5	138.0	10.50	24.05	148.39
C.D. (0.05)	NS	1.05	NS	NS	1.07	15.38	NS	10.4	1.50	1.37	5.04

for sustainable intensification of rice-fallows in Eastern India (Fig. 5.7). The experiment was conducted in a split plot design. The treatments comprised of different tillage and crop establishment practices as main plot treatments and weed management practices as subplot treatments. The main plot treatments were line puddled transplanted rice (LPTPR), conventional-tilled direct-seeded rice (CTDSR) and zero-tilled direct-seeded rice (ZTDSR). The sub-plot treatments were weedy check (WC), pre-emergence (PE) pyrazosulfuron-ethyl at 25 g/ha *fb* post-emergence (PoE) bispyribac-sodium at 25 g/ha, PE pyrazosulfuron-ethyl at 25 g/ha *fb* PoE cyhalofop butyl + penoxulam at 135 g/ha and weed free check (WFC). The experiment was planned to be carried out in a rice-wheat-greengram system. The major weed flora in rice included *Echinochloa colona* L., *E. crusgalli* L., *Leptochola chinensis* L., *Digitaria sanguinalis* L., *Eleusine indica* L., and *Dactyloctenium aegyptium* L. among grassy weeds; *Oldenlandia corymbosa* L., *Commelina benghalensis* L., *Ludwigia parviflora* L., and *Eclipta prostrata* L. among broad-leaved weeds; and *Cyperus rotundus* L., and *C. difformis* L. among sedges. Results of the study revealed that among weed management practices, the treatment PE pyrazosulfuron-ethyl *fb* PoE cyhalofop butyl + penoxulam led to effective suppression of weed density as well as biomass in rice. The significantly higher grain yield of rice (5.99 t/ha) was obtained with CTDSR × WFC. However, it was observed statistically at par with ZTDSR × PE pyrazosulfuron-ethyl *fb* PoE bispyribac-sodium (5.94 t/ha).

Fig. 5.7. View of experimental fields

6. Pulses

Genetic Enhancement of Pigeon Pea for Yield and Biotic Stress Resistance

Evaluation of Short Duration Pigeon Pea Germplasm

The pigeon pea lines ICPL-92047, ICPL-81-3, ICPL-88034 and ICPL-20325 which were found promising among the short duration group during the last year were evaluated with respect to yield and yield characters. Among them, ICPL-81-3 and ICPL-92047 were found to be best suited for eastern plateau and hill region and can be harvested in five months (Table 6.1).

Twenty two short duration genotypes collected from Minicore collections of ICRISAT, Hyderabad *viz.*, ICP-7, ICP-348, ICP-38, ICP-3046, ICP-13828, ICP-14638, ICP-11477, ICP-20338, ICP-11321, ICP-12680, ICP-14900, ICP-20329, CO-1, ICP-11690, ICP-11946, ICP-14819, ICP-15049, ICP-16309, ICPB-2039, CO-5, ICPH-2431, ICPL-13828ICPL-92047, ICPL-81-3, ICPL-88034 and ICPL-20325 were evaluated with respect to yield characters and yield. All the characters were found to be significant for these 22 early genotypes (Fig. 6.1) (Table 6.2).

Performance of Advance Breeding Lines in AICRP/State Trials

- In chickpea, one entry 'DBGC 3' was put to IVT of AICRP on chickpea for evaluation under rainfed condition during 2021-22. The same genotype has been promoted to AVT-1 of AICRP on Chickpea for timely sown condition. This genotype 'DBGC 3' was also proposed for evaluation in the chickpea trials for Bihar.
- In lentil, one entry 'DBGL 105' was put to IVT of AICRP on MULLaRP for evaluation during 2021-22.

Performance of Advance Breeding Lines in WiltSick Nursery

Five genotypes each of chickpea (DBGC 1, DBGC 2, DBGC 3, DBGC 4 and RCEC 2310) and of lentil (DBGL 62, DBGL 105, DBGL 135, RCEL 19-1 and RCEL 19-2) were put to pathological trials for assessment of wilt reaction at Tirhut College of Agriculture, Dholi (Muzaffarpur) during the year 2020-21. The data showed that all the genotypes

Table 6.1. Evaluation of promising genotypes of pigeon pea (short duration)

Genotype	Days to 50% flowering	Plant height (m)	Days to harvest	Pod bearing length (m)	Yield (q/ha)	Shelling %	No. of seeds per pod	100 seed weight (g)	Harvest index
ICPL-92047	83	2.2	148	1.2	11.48	75.00	3.8	24.5	24.5
ICPL-88034	97	2.2	148	1.2	8.14	66.67	4.2	17.27	17.3
ICPL-81-3	92	2.2	148	1.2	13.65	75.00	3.9	14.9	14.9
ICPL-20325	68	1.65	162	1.0	6.81	80.00	3.8	31.1	31.1

Table 6.2. Performance of short duration genotypes of pigeon pea for yield and yield characters

S. No.	Character	Range	C.D	C.V.
1.	Days to 50% flowering	52-168	1.39	0.82
2.	Plant height (m)	1.2-3.9	1.54	1.08
3.	Days to harvest	160-278	1.82	1.1
4.	Pod bearing length (m)	0.9-2.0	1.47	1.04
5.	Yield (q/ha)	1.84-27.50	1.81	3.67
6.	Shelling %	50.0-81.0	15.55	27.71
7.	No. of seeds per pod	3.2-7.2	3.07	6.46
8.	100 seed weight (g)	5.03-14.48	0.68	16.93
9.	Harvest index	2.25-111.11	2.96	5.99

Fig. 6.1. Genetic diversity of Pigeon pea germplasm

of chickpea (except DBGC 2) and two genotypes of lentil expressed resistant to moderately resistant reaction against chickpea wilt and lentil wilt, respectively (Table 6.3). In lentil, the genotype 'RCEL 19-1' showed mortality percent substantially more than the susceptible check 'Sehore 74-3', indicating that it could be a better susceptible check than the existing one (Sehore 74-3) for assessing wilt sick reaction of lentil genotypes in AICRP pathological trial.

Table 6.3. Wilt reaction of chickpea and lentil genotypes at TCA, Dholi (2020-21)

Chickpea			Lentil		
Test genotypes	Mean wilting (%)	Wilt reaction	Test genotypes	Mean wilting (%)	Wilt reaction
DBGC 1	7.50	R	DBGL 62	11.25	MR
DBGC 2	38.33	S	DBGL 105	6.25	R
DBGC 3	11.58	MR	DBGL 135	42.50	S
DBGC 4	20.81	MR	RCEL 19-1	75.00	S
RCEC 2310	14.50	MR	RCEL 19-2	35.00	S
JG 62 (S-check)	86.25	S	Seohore 70-3 (S-check)	58.75	S

R: resistant; MR: Moderately resistant; S: susceptible

Station trials (2020-21)

- **Chickpea:** A station trial comprising 11 genotypes (including BG 3043 and Shubhra as the check varieties) was conducted under normal irrigated condition (sown during the 3rd week of November 2020) following randomized complete block design (RCBD) in three replications. The test entry 'RCEC 3' (1703 kg/ha), with 100 seed wt of 22.76 g and maturity period of 134 days showed an yield advantage over the best check 'BG 3043' (1398 kg/ha) by more than 21% under normal irrigated condition (Table 6.4). This genotype has optimum Zn (56 ppm) and Fe (47 ppm) contents. A *Kabuli* chickpea genotype 'RCECK 16-4', *which has determinate growth habit*, yielded (1671 kg/ha) significantly more than its one of the parents 'Shubhra' (1252 kg/ha). Although its seeds contained comparable Zn and Fe contents, the seed size was lesser than that of 'Shubhra' (32.44 g/100 seed).

Besides, two preliminary yield trials (PYTs) were also conducted comprising breeding lines selected from previous year (2019-20) breeding materials received as ICARDA nursery. In PYT-I, one line '13125' yielded (1853 kg/ha) substantially more than the check 'Shubhra' (906 kg/ha) with comparable seed size (27.51 g/100 seeds) and significantly greater Zn (49 ppm) and Fe (57 ppm) contents (Table 6.5). In the second trial (PYT-II),

Table 6.4. Mean performance of promising chickpea genotypes under normal sown conditions at ICAR RCER, Patna (2020-21)

Genotype	Yield (kg/ha)	100 seed wt (g)	Maturity period (day)	Zn (ppm)	Fe (ppm)
RCEC-13	1072	15.45	129	46	60
RCEC-4	788	19.37	129	55	79
RCEC-1	1299	26.47	131	32	24
RCEC-3	1703	22.76	134	56	47
RCEC-4	1249	25.29	127	72	31
RCEC-7	807	21.91	128	25	54
RCEC 2310	1640	18.02	130	52	31
RCECK16-4	1671	27.96	132	41	37
RCECK16-2	733	21.96	131	60	39
Shubhra (check)	1252	32.44	129	42	50
BG 3043	1398	19.75	130	40	67
LSD (P=0.05)	245	1.39	0.74	--	--

Table 6.5. Mean performance of promising Kabuli chickpea genotypes (received fromICARDA) in preliminary yield trial-I (2020-21)

Genotype	Yield (kg/ha)	100 seed wt (g)	Maturity period (day)	Zn (ppm)	Fe (ppm)
Shubhra	906	30.52	129	28	35
13122	765	29.64	139	74	99
13125	1853	27.51	140	49	57
13126	1108	28.07	141	48	19
13127	1163	30.63	142	34	54
13128	1408	29.21	141	45	115
13131	1017	28.54	141	47	28
13132	1824	25.00	135	39	52
13134	1278	28.66	136	57	65
13135	1365	22.47	138	31	105
LSD (P=0.05)	198	1.09	1.10	--	--

the genotype '13222' showed a yield advantage of more than 57% over the check variety 'Shubhra' with comparable seed size, Zn and Fe contents (Table 6.6).

- **Lentil:** Two preliminary yield trials, each comprising 13 treatments (including five check varieties), were conducted under normal sown condition (3rd week of November 2020) following randomized complete block design (RCBD) in two replications to select the productive lentil genotypes along with high Zn and Fe contents for the north east plain zone (NEPZ). In the first trial, none of the test genotypes outyielded the best check 'IPL 220'; however, two lines (59024 and 59025) excelled the best check for Zn and Fe contents (Table 6.7). In the second trial, two lines (59047 and 59049) outyielded the best check 'IPL 220' (1958 kg/ha), and both the lines were comparable to the check for Zn and Fe contents (Table 6.8). During the year 2020-21, ICARDA nursery comprising a total of 80 genotypes was received. These genotypes were grown in augmented design with 'IPL 220' as the check. 8 lines neither flowered nor did set pods. A total of 11 lines excelled significantly the check 'IPL 220'. A total of 40 lines (50% selection intensity) that yielded satisfactorily were selected for further evaluation during the forthcoming winter season (2021-22).

Table 6.6. Mean performance of promising Kabuli chickpea genotypes (received from ICARDA) in preliminary yield trial-II (2020-21)

Genotype	Yield (kg/ha)	100 seed wt (g)	Maturity period (day)	Zn (ppm)	Fe (ppm)
Shubhra	1339	32.22	129	28	35
13222	2111	29.05	136	32	44
13225	835	25.37	138	31	41
13226	1627	28.98	135	33	25
13227	797	28.00	139	127	118
13228	1340	35.61	137	62	79
13231	1251	30.75	130	35	54
13232	1078	30.24	137	52	61
13234	883	30.57	141	51	62
13235	422	25.53	140	56	108
LSD (P=0.05)	205	1.29	1.14	--	--

Table 6.7. Mean performance of promising lentil genotypes (received from ICARDA) in preliminary yield trial-I (2020-21)

Genotypes	Yield (kg/ha)	100 seed wt (g)	Maturity period (day)	Zn (ppm)	Fe (ppm)
59001	1350	2.87	111	60	107
59016	1085	2.91	112	68	44
59017	1504	1.90	109	88	59
59021	1307	2.45	111	70	67
59023	1107	3.72	100	67	57
59024	1515	2.67	99	59	100
59025	1511	2.07	113	79	104
IPL 220	1854	1.94	107	58	84
KLS 218	1765	1.83	107	56	81
LSD(P=0.05)	285	0.34	1.74	--	--

Table 6.8. Mean performance of promising lentil genotypes (received from ICARDA) in preliminary yield trial-II (2020-21)

Genotypes	Yield (kg/ha)	100 seed wt (g)	Maturity period (day)	Zn (ppm)	Fe (ppm)
59034	1243	2.98	114	48	90
59036	1390	1.93	114	82	69
59037	1819	2.41	106	69	62
59042	1552	2.31	112	82	102
59043	1408	2.35	112	70	106
59045	1084	2.80	116	74	54
59047	2072	2.69	105	72	63
59049	2161	2.64	105	69	81
59050	1357	2.72	101	44	102
IPL 220	1958	1.99	109	66	87
LS-D(P=0.05)	265	0.29	1.64	--	--

- **Grasspea:** During the year 2020-21, a total of 48 low ODAP lines of grass pea were received from ICARDA nursery. These lines were evaluated as per layout and design provided by ICARDA. Low ODAP variety 'Ratan' was used as the check. Based on yield performance of test lines vis-à-vis check variety, 7 lines (75016, 75017, 75022, 75024, 75040, 75046 and 75049) were found promising.
- **Breeding materials and germplasm maintained during 2020-21**: Several advance breeding lines of *Desi* chickpea (DBGC 1, DBGC 2, DBGC 3, DBGC 4, RCEC 2310, RCEC 3, RCEC 6003, RCEC 6059, RCEC 6141 and RCEC 6125) and *Kabuli* chickpea (RCECK 16-2 and RCECK 16-4), ICRISAT germplasm line (ICC 4958) and released Desi (Pusa 256, Pusa 372, Pusa 547, Pusa 1103, Pusa 3043, KWR 108, JG 14, JG 16, GNG 1581 and GNG 2299) and Kabuli (IPCK 2002-29) chickpea varieties were grown and maintained. Seeds were individually harvested and kept for their utilization in the forthcoming *rabi* season 2021-22.

In lentil, 19 advance breeding lines and 18 released varieties were grown, purified and maintained. A "super early" advance breeding line **'RCEL 19-1'** (ILWL 118 × DPL 58) that started flowering from 45 days after sowing and matured in about 95 days after sowing was grown and multiplied. Although the line matures very early, it is highly susceptible to root diseases (dry root rot, collar rot and Fusarium wilt). This attribute makes it highly suitable for its use as a "susceptible" check in pathological trial.

Pulse Seed Hub

Under the aegis of NFSM funded mega project on "Creation of seed hubs for increasing indigenous production of pulses in India", Breeder seed production of pigeonpea (IPA 203) and chickpea (Pusa 3043 and GNG 2299) was taken up at ICAR RCER, Patna during the year 2020-21. In lentil, foundation seeds of 'IPL 220' and TL seeds of 'PL 8' were produced. In addition, quality seeds of mungbean (Samrat, Virat, Shikha, IPM 2-3 and IPM 2-14) and urdbean (IPU 2-11) were also taken up at ICAR RCER, Patna. At KVK, Buxar, quality seeds of red gram (IPA 203) and chickpea (RVG 202) were taken up in participatory mode. Details of quality seeds produced are mentioned in the (Table 6.9).

Table 6.9. Quality seeds of pulses produced under Pulse Seed Hubs during the year 2021

Crop	Variety	Class of Seed	Quantity (kg)
Lentil	HUL 57	T/L	2500
	PL 8	T/L	500
	IPL 220	F/S	1000
	IPL 316	F/S	12100*
Chickpea	Pusa 3043	B/S	2000
	Pusa 3043	F/S	900*
	GNG 2299	B/S	500
	RVG 202	C/S	9000*
	Shubhra	Nucleus, T/L	100
Pigeonpea	IPA 203	Nucleus	20
		B/S	2000
		T/L	4000*
Mungbean	Samrat	T/L	600
	IPM 02-14	T/L	150
	IPM 02-3	T/L	450
	Shikha	T/L	200
	Virat	T/L	200
Urdbean	Uttara	T/L	50
	IPU 02-11	T/L	50
Total			36,320

B/S: Breeder seed; F/S: Foundation seed; CS: Certified seed; T/L: Truthfully labelled seed

*Produced under Pulse seed hub, KVK, Buxar

Field Evaluation of *Trichoderma* Isolates against Wilt Complex in Chickpea and Lentil

Four *Trichoderma* isolates (T16, T17, T18 and T19) which were found effective *in-vitro* and two years of validation in field conditions were further evaluated for their efficacy under field conditions against wilt complex diseases in lentil (Var: Sehore Local and HUL 57) and chickpea (Var: JG 62 and L550). Seed treatment was done with *Trichoderma* @ 10 g/kg seeds before sowing of crops. To compare efficacy, seeds treated with Azoxystrobin 23%SC @ 0.2% and untreated seeds (control) were also sown and disease incidence (mortality %) was recorded at 30 DAS, 50DAS and 70DAS (Table 6.10). Isolates T 18 and T19 were found most effective where disease incidence was significantly lower as compared to control. However, their efficacy was lesser than chemical fungicide (Azoxystrobin 23%SC).

Pigeonpea Evaluation under Controlled Condition

A total of 61 pigeonpea germplasms/genotypes including two lines of ICAR RCER Patna namely, ICAR PP-01 and ICAR PP-02, were tested along with IPAC-79 (check line), under controlled submergence environment to evaluate excess moisture tolerant ability (Fig. 6.2). Pigeonpea germplasm, i.e., IPAC-79 has been registered by IIPR, Kanpur (registration No.: INGR20023), for its excess moisture tolerant traits. Controlled condition testing and evaluation were done in the artificially developed submergence pond. For testing, each genotype was planted in four pots and in each pot, there were 4 plants. To maintain minimum 4 plants in each pot, 8 seeds of pigeonpea per pot were sown and thinned to maintain 4 plants and put in water for 96 hrs before the schedule of submergence treatments to ensure that only healthy plants may take part in the submergence treatment.

Fig. 6.2. Pigeonpea in pots in control conditions (left) and after submergence trenches (right)

Table 6.10. Field evaluation of *Trichoderma* isolates against wilt complex in chickpea and lentil

Lentil				Chickpea			
Treatments	Mortality (%) due to wilt complex diseases			Treatments	Mortality (%) due to wilt complex diseases		
	30 DAS	50 DAS	70 DAS		30 DAS	50 DAS	70 DAS
Variety: Sehore Local				Variety: JG 62 (Desi Type)			
T 16	1.61^{C}	10.27^{C}	14.39^{B}	T 16	1.1^{b}	4.96^{b}	6.19^{b}
T 17	3.13^{B}	10.62^{C}	15.92^{B}	T 17	1.3^{b}	4.62b	4.98^{c}
T 18	2.25^{C}	12.37^{B}	14.3^{B}	T 18	0.7^{c}	2.11^{cd}	3.33^{d}
T 19	1.76^{C}	10.76^{BC}	13.64^{B}	T 19	1.0^{b}	2.53^{c}	3.47^{d}
Azoxystrobin 23%SC	1.59^{C}	9.31^{C}	10.92^{C}	Azoxystrobin 23%SC	0.5^{c}	1.09^{d}	2.01^{e}
Control	8.18^{A}	19.08^{A}	32.55^{A}	Control	2.3^{a}	8.33^{a}	9.6^{a}
Variety: HUL-57				Variety: L 550 (Kabuli Type)			
T 16	3.1^{C}	8.66^{C}	11.97^{B}	T 16	1.0^{b}	2.0^{b}	2.23^{b}
T 17	3.27^{C}	7.82^{D}	12.36^{B}	T 17	1.0^{b}	2.2^{b}	3.64^{b}
T 18		10.69^{B}	$11.62B^{C}$	T 18	0.7^{c}	2.0^{b}	2.44^{b}
T 19		9.03^{C}	10.81^{C}	T 19	1.3^{b}	1.6^{b}	2.31^{b}
Azoxystrobin 23%SC		7.22^{D}	9.01^{D}	Azoxystrobin 23%SC	0.9^{c}	1.4^{b}	1.74^{b}
Control		15.32^{A}	23.59^{A}	Control	3.2^{a}	5.0^{a}	6.92^{a}

DAS: Days after sowing

15 days old pigeonpea seedlings, grown in pots were subjected to submergence treatment in seepage proof two feet deep trenches and at least 5 cm water was maintained for whole submergence period as per the duration prescribed for particular cycle of submergence.

All the 52 pigeonpea genotypes were tested under three set of submergence conditions ranging from 120 hours (5 days) to 168 hrs (7 days). Each set of submergence treatment had two cycles of submergence (Table 6.11). Subsequently, second cycle of submergence was imposed over survived genotypes after two weeks of first cycle.

Pigeonpea survival data were recorded for every cycle and each set of submergence treatment is presented in Table 6.12. Data were presented only for those genotypes for which survival rate was more than 50 percent after successful completion of second cycle of submergence (Fig. 6.3).

Table 6.11. Schedule of submergence cycle and duration

Subset description	First cycle of submergence	Second cycle of submergence
Subset 1	120 hrs. (5 days)	168 hrs, (7 days)
Subset 2	168 hrs (7 days)	120 hrs. (5 days)
Subset 3	168 hrs. (7 days)	168 hrs. (7 days)

Table 6.12. Best performing genotypes under controlled submergence (Set 3)

Genotype	First cycle of submergence (168 hrs. or 7days)	Second cycle of submergence (168 hrs. or 7days)
ICAR RCER PP 01	81.25	68.75
ICAR RCER PP 02	75.0	62.25
ICP 9353	68.75	56.25
ICP 9516	68.75	56.25
ICP 9228	62.50	56.25
ICP 9397	56.25	50.00
IPAC-79 Check	56.25	50.00

Fig. 6.3. Performance of pigeonpea submergences after first and second cycle of submergence subset 1

Field evaluation of promising pigeonpea line

These pigeonpea genotypes which tolerated water stress for 168 hrs (7 days) submergence exposures twice in two-week interval was taken up. Best performing pigeonpea genotypes, having survival percentage of more than 50% under controlled submergence (subset 3), was promoted for real field evaluation. Pigeonpea genotypes, found relatively tolerant to excess moisture under controlled environment, were further tested under field conditions for evaluation and multiplication (Fig. 6.4). These genotypes were ICAR RCER PP 01, ICAR RCER PP 02, ICP 9353, ICP 9516, ICP 9228, ICP 9397 and IPAC-79 (check).

Fig. 6.4. Eavluation of excess moisture tollerent genotypes under filed conditions

Multiplication of faba bean varieties

Swarna Gaurav and *Swarna Suraksha,* first ever faba bean varieties, developed by the institute were recommended by Central Varietal Release Committee (CVRC) for cultivation under rainfed as well as irrigated ecology. Both the varieties were multiplied for seed distribution among the farmers.

Scaling up Climate Smart Agriculture through Mainstreaming Climate Smart Villages (CSVs) in Bihar

An inter-institutional project "*Scaling Up Climate Smart Agriculture (CSA) through Mainstreaming Climate Smart Villages (CSVs) in Bihar*" funded by **National Adaptation fund for Climate Change (NAFCC)** was implemented in Patna (5 villages each in Fatuah and Daniyama blocks) and Nalanda (5 villages each in Nagarnausa, Noorsarai and Chandi blocks) districts of Bihar. Under the project, a total of 25 climate smart villages and 6 registered Farmers' Interest Groups (FIGs) were established. Details of activities performed under the project are mentioned in (Table 6.13-6.15).

Table 6.15. Capacity building

S. No.	Programmes conducted	2020-21
1.	Training	2
2.	Field day	5
3.	Exposure visit	2
Grand total		9

Table 6.13. Total inputs provided for implementation of different technologies (2020-21)

S. No.	Crop	Establishment method	Seed distributed Variety	Quantity (kg)	Herbicides provided
1.	Moong bean	Zero tillage	Samrat	1000	100 L Pendimethalin (30 EC)
2.	Rice	Direct seeding	Swarna Shreya	8300	120 L Pendimethalin (30 EC), 9.6 L Bispyribac Sodium (10% SC) and 9.6 kg Pyrazosulfuron Ethyl
3.	Lentil	Zero tillage	HUL-57	1000	Emidachloroprid and Spinosad
4.	Wheat	Zero tillage	HD 2967	2500	125 L of Sulfosulfuron (75%) + Metsulfuron Methyl (5% WG) and 125 L Pendimethalin (30 EC)

Table 6.14. Total area and productivity of different technologies implemented (2020-21)

Block	ZT-Moong bean		DSR		ZT-wheat		ZT-lentil	
	Area (Acre)	Yield (q/acre)	Area (Acre)	Yield (q/acre)	Area (Acre)	Yield (q/acre)	Area (Acre)	Yield (q/acre)
Fatuha	8.69	0.75	8.25	11.24	11.94	19.43	6.37	6.99
Daniyawan	33.94	2.59	21.56	10.24	28.4	18.04	5.90	7.34
Nagarnausa	22.46	3.58	5.7	8.54	25.84	17.9	7.21	5.93
Chandi	35.0	4.05	15	10.95	25.0	20.16	8.43	5.94
Noorsarai	26.16	4.15	21.84	14.64	32.71	17.8	15.0	5.96
Grand total	126.25	-	72.35	-	123.89	-	42.91	-

7. Fruits

Exploration and Collection of Jackfruit Germplasm

In the year 2021, explorations were carried out to collect offseason vegetable type jackfruit germplasm (Fig. 7.1). From surveys in Ranchi district, 3 jackfruit genotypes were identified which gave fruiting in offseason (October to January) and suitable as vegetable purpose in tender stage (1-2 kg). Their yield potential varied from 80 to 120 kg/tree. One early vegetable type farmer's jackfruit variety Bandhu Amxi Gathana (IC-0625182) found very profitable and it gave average total income of Rs. 29753/- per tree during the offseason (December-March) to the custodian farmer (Table 7.1).

Fig. 7.1. Offseason jackfruit collected from farmer's field

Identification of Unique Mulberry Genotype

A promising spreading type mulberry genotype identified from the ICAR RCER FSRCHPR farm (Fig. 7.2). Based on mulberry DUS guidelines, it has truncate type leaves, acuminate leaf apex, serrated leaf margin, ovate leaf shape and short petiole length. It has very long fruit length (8.56±0.25 cm) with bluish black in fruit colour. The average fruit weight (g) was 4.30±0.41 and average yield (kg/plant) was 35.59±4.96. The TSS of fruit was 21.97°B and acidity 0.30%.

Fig. 7.2. Promising mulberry genotype (ICAR RCER Mulberry Sel. - 1)

Table 7.1. Year wise offseason jackfruit yield and income

Month	2018-19		2019-20		2020-21	
	Yield (kg/plant)	Income (Rs.)	Yield (kg/plant)	Income (Rs.)	Yield (kg/plant)	Income (Rs.)
December	60	4800	56	4480	54	4320
January	220	13200	148	8880	133	7980
February	103	5150	247	12350	153	7650
March	84	4200	149	7450	176	8800
Total	467	27350	600	33160	516	28750

Fruit Crops Varieties Released by SVRC

Litchi Variety Swarna Madhu

It is regular bearing and high yielding (31.81 kg/plant) whose fruit weight ranged from 20-23g, and pulp recovery was 74.95%. It had TSS around 18.26°B and acidity (0.35%). The variety had high juice recovery (>45%). The variety is moderately resistant to seed borer. It is less vigorous than Shahi and China (Fig. 7.3).

Fig. 7.3. Litchi variety Swarna Madhu (CHL-8)

Fig. 7.4. Bael variety Swarna Vasudha

Bael Variety Swarna Vasudha

It is a semi vigorous, regular bearing, which has fruit weight ranging from 1100g to 1800g, and high yield under rainfed condition (43.8 kg/plant). The pulp recovery was 82.41%, TSS 40.30°B and acidity 0.54% (Fig. 7.4). The variety had low seed content (<2%) with thin shell (<2mm). The plant is semi vigorous having 34% less height than check variety Pant Sujata.

Screening of Bael Genotypes for Fruit Cracking

Most of the bael genotypes are susceptible to cracking. During 2021-22, at ICAR RCER, FSRCHPR 37 bael genotypes were screened against severity of cracking (Fig. 7.5). The cracking percentage varied from 0 to 81.48. The highest cracking was reported in ICAR RCER BS 9-2. The genotypes such as ICAR RCER BS 6-4, 6-6, 7-2, 7-3, 8-5 and 9-6 showed no cracking.

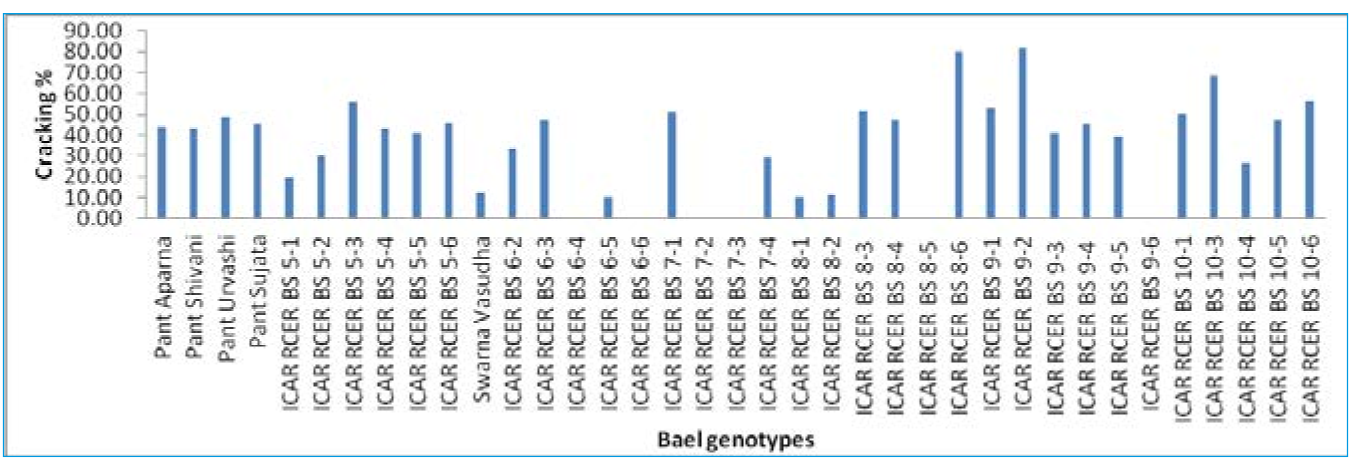


Fig. 7.5. Bael genotypes with their fruit cracking percentage

8. Vegetables

Development of Multiple Disease Resistant Hybrids in Solanaceous Crops

Evaluation of Bacterial wilt resistant germplasm in brinjal

Among forty one genotypes of brinjal collected from ICAR-NBPGR, New Delhi for bacterial wilt resistance, ten genotypes were showing resistance to bacterial wilt during the first year (2020-21) of evaluation under artificial wilt sick conditions. During the second year (2021-22) of evaluation, only one genotype EC-467271 showed resistance to bacterial wilt under artificial wilt sick conditions.

Evaluation of Chilli genotypes for yield and yield characters

Chilli genotypes (8) collected from various sources were evaluated for yield and other characters. Wide variability was present was among them for all the characters studied (Table 8.1). Variety Aparna was high yielding. Variety Haldi Pada showed yellow fruits at mature ripe stage (Fig. 8.1). Based on second year data, potential genotypes will be selected for crossing programme.

Table 8.1. Evaluation of chilli genotypes for yield and yield characters

Genotype	Yield (q/ha)	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit color (Green Stage)	Fruit color (Matured Ripe Stage)
Ujwala	32	2.4	6.4	0.8	Green	Red
Pusa Jwala	25	2.2	8.9	0.6	Light green	Red
Pusa Sadabahar	20	3.2	5.1	1.2	Green	Red
Arka Megha	53	4.8	10.4	0.9	Dark green	Dark red
Aparna	73	5.4	8.7	0.9	Green	Red
Haldi Pada	17	2.4	6.7	0.8	Green	Yellow
Kullu local	17	2.8	7.5	0.6	Green	Red
New collection	12	4.6	5.4	1.7	Green	Dark red

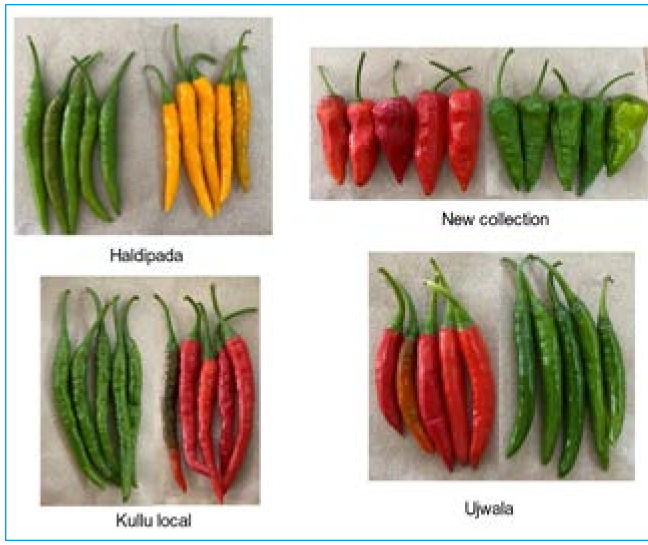


Fig. 8.1. Genetic diversity of chilli genotypes

Identification of Bacterial Wilt Resistant Tomato Variety

Swarna Prakash (RCDT 1314)

Swarna Prakash (RCDT 1314) (Fig. 8.2) was identified by Institute Variety Release Committee suitable for cultivation under different zones of Jharkhand. It is resistant to bacterial wilt (89% plant survival) and high yielding (45-50 t/ha) (Fig 3). It shows vigorous growth, determinate growth habit, plant height (75-80cm), avg fruit weight 90-100 g, TSS-3.0-3.8^{0}brix, Acidity (%)-0.18-0.20, Ascorbic acid (mg/100g fruit)-10-15, round slightly flattened fruits with attractive dark red colour at maturity.


Fig. 8.2. Swarna Prakash

Genetic Resource Management in Vegetable crops

Identification of bacterial wilt resistant chilli varieties

Swarna Arohi (HC-69)

Swarna Arohi (HC-69) (Fig. 8.3) was identified by Institute Variety Release Committee suitable for cultivation under different zones of Jharkhand. It has been developed through hybridization and selection from F_8 generation of the cross HC – 62 x HC – 34 – 2 – 1 – 1. It is high yielding (20-22 t/ha) with dark green upright fruits having good source of vitamin A (211.87 mg/100g dry weight), vitamin C and high pungency (Total SHU 50431, Capsaicinoids 0.31g/100g dry weight) at green chilli stage. It is resistant to bacterial wilt under natural field condition with 91% survival rate.

Fig. 8.3. Swarna Arohi

Swarna Apurva (HC-70)

Swarna Apurva (HC-70) (Fig. 8.4) was identified by Institute Variety Release Committee suitable for cultivation under different zones of Jharkhand. It has been developed through hybridization and selection from F_8 generation of the cross HC – 62 x HC – 34 – 1 – 4 – 1. It is high yielding (20-25 t/ha) with dark green fruits having good source of vitamin A (246.94 mg/100g dry weight), vitamin C and high pungency (Total SHU 90194, Capsaicinoids 0.56g/100g dry weight) at green chilli stage. It is resistant to bacterial wilt under natural field condition with 89% survival rate.

Fig. 8.4. Swarna Apurva

Ridge gourd

RCRG-111 (Fig. 8.5) was identified to be promising and submitted under AICRP (VC) in 2019 for multi location testing. It was developed by individual plant selection and self pollination from local collection. It is high yielding (20-22 t/ha) with long dark green fruits, fruit length: 20-22 cm, medium ridges, soft flesh with less fibre, sequential fruiting habit, early flowering and fruiting, suitable for rainy and summer season and tolerant to powdery mildew under field conditions.

Fig. 8.5. RCRG-111 and sequential fruiting habit

Sponge gourd

RCSG-2 (Fig. 8.6) was identified to be promising and submitted under ICAR-AICRP (VC) in 2020 for multi location testing. It was developed by individual plant selection and self pollination from local collection. Fruits are long, dark green with fruit length: 30-35 cm,

Fig. 8.6. RCSG-2

fruit diameter: 6.0-6.2cm, fruit weight 200-250 g, soft flesh with less fibre, high yielding (22-25 t/ha), early flowering and fruiting, suitable for rainy and summer season.

Cucumber

RCCV-158 (Fig. 8.7) was identified to be promising and submitted under ICAR-AICRP(VC) in 2021 for multi location testing. It was developed from HC-50×*Cucumis hardwickii* 26-3 F_{10} interspecific hybridization and pure line selection. It is high yielding (35 t/ha) with green fruits having stripes (white tinge), avg fruit weight: 150-200g, fruit length: 15-16cm, fruit diameter: 4-4.5cm, avg yield/plant: 4-5 kg. It is tolerant to downy mildew disease under natural conditions and suitable for cultivation in both rainy and summer seasons.

Fig. 8.7. RCCV-158

French bean

Evaluation of French bean for disease resistance and horticultural traits:

A total of seventy-four genotypes of French bean (37 each of bush and pole type) including 2 commercial checks were evaluated for disease incidence in *kharif* season of 2021. Major disease occurrence in the season were reported for anthracnose, angular leaf spot, root rot, mosaic and rust on French bean in EPHR (Fig. 8.8). Ten genotypes showed higher degree of resistance/tolerance against anthracnose under field condition as described in (Table 8.2).

Table 8.2. Degree of field resistance or tolerance of French bean genotypes against anthracnose

Genotypes	Severity scale	PDI	Disease reaction
HAFB-2	1	20	Moderately Resistant
HAFB-6	2	30	Tolerant
VLBFB-30	2	30	Tolerant
DWBFB-57	2	30	Tolerant
HAPB-1	1	20	Resistant
HAPB-5	2	25	Moderately Resistant
HAPB-7	2	30	Tolerant
HAPB-22	2	25	Moderately Resistant
HAPB-33	0	10	Highly Resistant
HAPB-34	3	40	Moderately Tolerant
Phalguni (RC)	0	10	Resistant

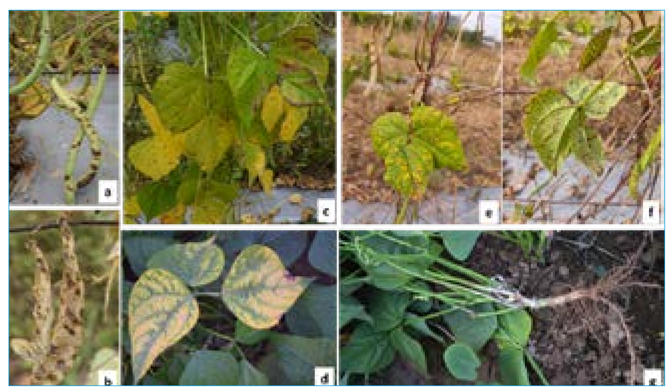


Fig. 8.8. Major diseases of French bean in ***kharif*** season: a) Anthracnose on green pods b) Anthracnose on dried pods c) Angular leaf spot d)Bean Yellow Mosaic Virus of beans e) Rust pustules on adaxial leaf surface f) Rust pustules on abaxial leaf surface g) Root rot of French bean

Vegetable soybean

Evaluation of vegetable soybean for horticultural and nutritional traits

Thirty six germplasm lines of vegetable soybean which were received from AVRDC-The World Vegetable Centre, Taiwan were evaluated in replicated trial during *kharif* season of 2021. Among the lines evaluated, AGS-458, the *Basmatic* vegetable soybean line, performed the best and recorded graded (2 &3-seeded) green pod yield of 13.34 t/ha and green seed yield of 6.52 t/ha (Fig.

8.9) followed by the non-*Basmatic* line AGS-404 which recorded graded green pod yield of 12.65 t/ha and green seed yield of 5.39 t/ha (Fig. 8.10). AGS-458 and AGS-404 recorded 37.95 and 30.82% yield increases over the variety Swarna Vasundhara (non- *Basmatic*; graded green pod yield 9.67 t/ha), respectively. Both the lines became ready for 1st green pod harvest in 65 days after sowing. The 100-green seed weight of AGS-458 and AGS- 404 were 73.33 and 56 g, respectively. Regarding mineral nutritional status (mg/100g edible unripe fresh shelled green beans), Ca content ranged from 37.82 (AGS-459) to 133.76 mg/100g (EC-595823), Mg content ranged from 54.18 (AGS-337) to 101.48 mg/100g (AGS-292), S content ranged from 53.30 (GC-84501-32-1) to 198.00 mg/100g (Swarna Vasundhara), K content ranged

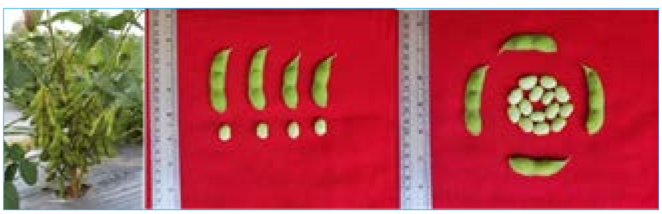


Fig. 8.9. Plant, pod and shelled seed of promising vegetable soybean line AGS-458

Fig. 8.10. Plant, pod and shelled seed of promising vegetable soybean line AGS-404

from 421.12 (EC-595824) to 725.40 mg/100g (AGS-292), Fe content ranged from 2.42 (AGS-456 & Harit Soya) to 4.68 mg/100g (AGS-610), Zn content ranged from 1.29 (Harit Soya) to 3.88 mg/100g (AGS-610), Cu content ranged from 0.43 (AGS-460) to 0.89 mg/100g (EC-595824), Mn content ranged from 0.65 (AGS-459) to 2.52 mg/100g (AGS-610) and Na content ranged from 0.11 (GC-84501-32-1) to 3.00 mg/100g (AGS-190). The crude protein content ranged from 7.25 (GC-84501-32-1) to 12.65 g/100g (Monato). The promising top yielding line AGS-458 also exhibited its worthiness with respect to content of protein (10.01g/100g), fat (8.28 g/100g), Ca (84.31 mg/100g), Mg (88.27 mg/100g), S (95.80 mg/100g), K (603.36 mg/100g), Fe (3.11 mg/100g), Zn (2.11 mg/100g) and Cu (0.65 mg/100g). The high yielding line AGS-404 was found promising for protein (7.70 g/100g), fat (5.15 g/100g), Ca (66.60 mg/100g), Mg (55.04 mg/100g), S (75.00 mg/100g), K (461.84 mg/100g), Fe (2.78 mg/100g), Zn (1.42 mg/100g), Mn (0.76 mg/100g) and Cu (0.61 mg/100g).

Enhancing Nutritional Security of Rural Households through Vegetable Based Nutri Garden in Bihar

In Nutri Garden model (100 m^2 area), twenty four vegetable species were selected for year round vegetable cultivation. The year round vegetable patterns were divided into three cropping seasons per year including *rabi* (mid-October to mid-March), pre *kharif* (mid-March to mid-June) and *kharif* (mid-June to mid-October). The highest yield potential was found in cropping pattern carrot-bottle gourd-water spinach (44.1±11.1 kg) followed by broccoli-yard long bean (YLB)-okra (43.9±7.7 kg) and palak-YLB-sponge gourd (42.4±5.7 kg). However, lowest yield production was observed in sem-okra-red amaranth (32.7±6 kg) pattern. Round the year production and yield of each pattern has been shown in (Table 8.3).

a. *Effectiveness of the Nutri-garden in fulfilling nutritional security*

Nutrition-wise, highest energy (23892 Kcal), protein (1849.9 g) and fat (143.2 g) were found in yard long

Table 8.3. Year round homestead production pattern and yield in 100m² model (in Kg)

S.N	Pattern	Rainy	Winter	Summer	Total
1	Okra-Broccoli-YLB	14.5±1.8	14±2.7	15.4±3.2	43.9±7.7
2	Water spinach-Carrot-Bottle gourd	14±2.3	12.9±3.6	17.2±5.2	44.1±11.1
3	Sponge gourd- Palak-YLB	14±1.4	12.6±2.5	15.8±1.8	42.4±5.7
4	Red Amaranth(for stem)-Sem-Okra	10±2.4	7±2.4	15.7±1.2	32.7±6
5	Basella-Cauliflower-YLB	8±2.3	15.2±3.4	14.8±2.1	38±7.8
6	YLB-Pea- Red Amaranth	17±3.8	12.3±.1.9	12±1.8	41.3±7.5
7	YLB-Spinach-Onion	14.2±1.2	10.3±2.3	13.1±3.1	37.5±6.6
8	Red Amaranth-Radish-Bottle gourd	10±1.6	12±4.2	16.2±2.3	38.2±8.1

YLB-Yard long bean

bean (YLB)- pea-red amaranth cropping pattern. It was calculated based on the food composition table of National Institute of Nutrition, Hyderabad. However, highest Vitamin A (1876380 IU) and Vitamin C (20888 mg) was found in Water spinach- Carrot-Bottle gourd followed by Basella-Cauliflower-YLB cropping pattern, respectively. Cropping pattern YLB-Pea- Red Amaranth was reported highest in thiamine (58.55 mg), riboflavin (68.52 mg) and niacin (653.7 mg) content. Similar pattern was also observed in respect of minerals content in YLB-Pea- Red Amaranth cropping pattern which contained highest amount of calcium (63078 mg), iron (34258 mg) and phosphorous (1180.7 mg). Nutrients availability from different vegetable based cropping system is shown in Fig. 8.11(a-d).

b. Economic Viability of Nutrigarden

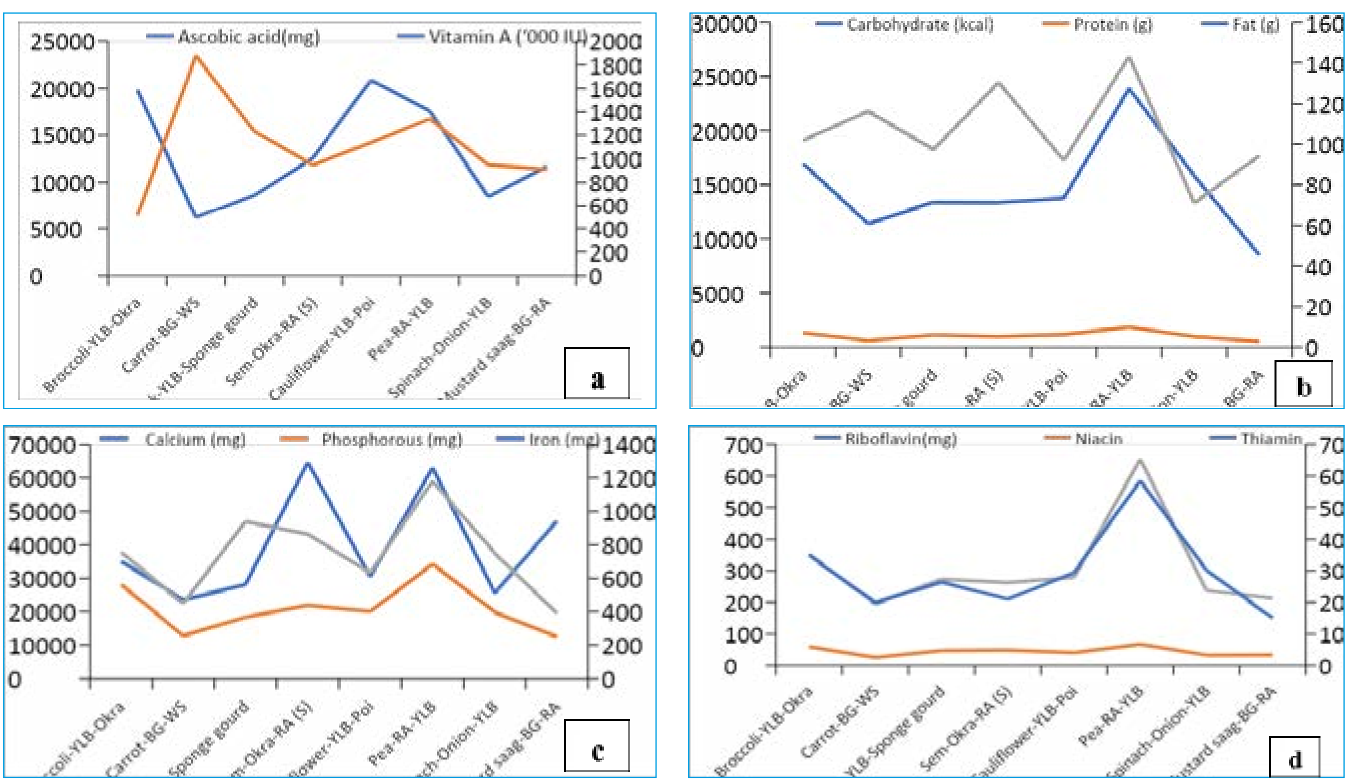
Total vegetable produced from 100m^2 area was recorded at 245.5 kg/year. Cost of seed and other input (chemicals, rope, bamboo sticks, GI wire) was Rs.1920/-. This study excluded labour cost as this type of kitchen garden was maintained by women or elder people of the respective household. Taking Rs.20 as average price of vegetables the total output from 100m^2 was Rs. 4910/ year. The benefit cost ratio was 2.57:1 from 100m^2 models (Table 8.4). Home garden model would be an effective approach to improve nutritional security while also providing an additional source of income, since the family would be able to sell a portion of the garden's output, reaching household self-sufficiency.

Table 8.4. Input Cost for Preparing Nutri Garden

S.N	Inputs	Cost (Rs)
1	Seed	430.00±60.00
2	Bio-pesticide	820.00±95.00
3	Others (Rope, GI wire, Bamboo sticks)	670.00±50.00
	Total cost	1920.00±48.00

Genetic enhancement of selected vegetable legumes for Eastern India

The relationship between seed coat colour, seed quality and yield related traits in yard long bean (*Vigna unguiculata* (L.) Walp.ssp. *unguiculata* cv.-gr. *sesquipedalis*) was measured. Total nine yardlong beans genotypes, three from each with different seed coat colours *i.e.* brown (IC-626154, IC-622602, IC-626152), black (IC-630383, IC-626147, IC-622602) and bicolor (YB-7, RCPY-1, RCPY-2) were selected for this study. Bicolor seed coat genotype exhibited highest germination percentage (85-100%) followed by brown (71-84%) and black (43-59%). The water uptake capacity was found



YLB-Yard long bean, WS-Water spinach, BG-Bottle gourd, RA- Red Amaranth, S-Stem

Fig. 8.11. Proximate composition 1b. Vitamin A and C 1c. Vitamin B (Riboflavin, Niacin and Thiamin) 1d. Calcium, Phosphorous and Iron obtained from different vegetable sequences grown in Nutri-garden

highest in bicolor genotype *i.e.* RCPY-2 (240%) followed by YB-7 (131.87%) and RCPY-1 (141.17%). Imbibition behaviour of yardlong bean genotypes of three different seed coat colour was observed. Imbibition curves indicated that water absorption and weight gain of seed were highest in genotypes having bicolor seed coat as compared to the genotypes consisting brown and black coloured seed coat.

Average pod length and pod yield per plant was also found highest in bicolor seed coat genotype RCPY-2 (37.64±11.03cm) and (1036.66±115.9 g/plant), respectively. Black seed coloured genotype (IC-630383, IC-626147) yielded green pod with purple tip (Fig. 8.12) while patches of purple colour were observed in whole pod in the genotypes IC-622601.

The percent disease intensity of yellow mosaic disease (YMD) caused by Mungbean Yellow Mosaic India Virus (MYMIV) was studied. Disease incidence among the genotypes of different seed coat colour ranged from 6.25 to 78.25%. All three bicolour seed coat genotypes (YB-7, RCPY-2 and RCPY-1) were found resistant to MYMIV. However, brown coloured seed coat lines showed moderate resistance (IC-622602, IC-626152) to resistant (IC-626154) in disease reaction. Genotype IC-626154, showed minimum mosaic incidence (6.25%). Black coloured seeds showed varied response to MYMIV. Among black coloured seeded genotypes, IC-630383 was moderately resistant and IC-622601 was resistant. However, genotype IC-626147 was found to be moderately susceptible against MYMIV with highest mean mosaic incidence of 78.25%. Bicolour genotype

Fig. 8.12. Black seed coat coloured genotype (IC-630383, IC-626147) yielded green pod with purple tip; 8.13. Black seed coat coloured genotype patches of purple colour were observed in whole pod in the genotypes IC-622601

RCPY-2 was identified as high yielding and disease resistant genotype and advanced form of cultivated type (large seeds with variable seed coat colors and rapid & uniform germination) while black seed coat was wild type (hard seededness and pod dehiscence).

Identification of Trait-Specific Germplasm in Dolichos bean

During *rabi* season of 2021-22, morpho-agronomic traits of dolichos bean (RCPD-1) was studied. Potential accession numbers for unique traits were identified from characterization dataset and validated at ICAR-RCER, Patna. Some of them are depicted in (Fig. 8.13). RCPD-1 is bush type, photo-insensitive, early in flowering (40 days), highly prolific bearer (130-150 pod per plant) and

Fig. 8.13. Profuse and early flowering b. long raceme c. prolific bearer and d. green long attractive pod of bush type (RCPD-1) dolichos pod

produced flattened dark green vegetable type pod (fewer and smaller seed at edible stage). This line was found superior to check variety Arka Sambhram. Nutritional analysis revealed that, this line was highly rich in protein (23.74%), calcium (390.47mg/100g DW), phosphorous (46.07 mg/100g DW), zinc (2.97.07 mg/100g DW) and iron (5.97 mg/100g DW). Amino acid profiling showed that it was good source of arginine, isoleucine, threonine and phenylalanine. The genotype RCPD-15 (Fig. 8.14) was identified with prolific bearer and anthocyanin rich and high pubescence in pod which

Fig. 8.14. RCPD-15; Prolific bearer, anthocyanin rich and high pubescence 6c. susceptible check

indicated a marker-trait for insect resistance. Similarly, another genotype RCPD-24 (Fig. 8.15) was identified for small anthocyanin content, less fibrous and bold seeded pod characteristics which was found suitable for both immature pod consumption and grain purpose.

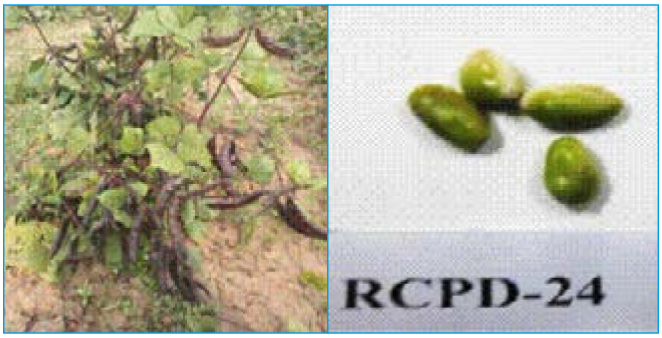


Fig. 8.15. RCPD-24; A small anthocyanin rich, bold seeded pod

Accession Number in Chilli Germplasm

One local, highly pungent, long & cylindrical chilli germplasm was found in Chireya village of East Champaran, Bihar and the seeds were deposited to ICAR-NBPGR (Accession No. IC-638518)

Field evaluation of potential bioagents and fungicides against wilt complex in cucurbits

Field evaluation of *Trichoderma* and fungicides against wilt complex in two cucurbits (bottleguard and cucumber) was carried out. Seed of these cucurbits were treated with two *Trichoderma* strains and two chemical fungicides (Azoxystrubin and Iprovalicarb 5.5% +Propineb 25%). Lowest disease incidence was observed in case of Azoxystrubin treated seeds in bottle guard while in the case of cucumber both the chemical fungicides were found to be equally effective (Fig. 8.16 and 8.17). However highest disease incidence was observed in untreated plants. Disease incidence for different treatments for both the crops at two different intervals has been presented in (Table 8.5). So, it is evident that use of chemical fungicides and *Trichoderma* are effective in controlling the wilt complex in cucurbits.

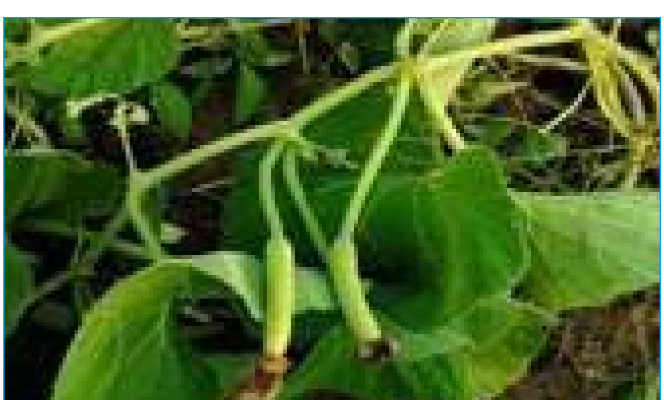


Fig. 8.16. Healthy bottle gourd plant

Fig. 8.17. Wilted bottle gourd plant

Table 8.5. Effect of different treatments on wilt complex disease in bottleguard and cucumber

Crop	Treatments	Mortality %	
		40 DAS	60 DAS
Bottle guard	T 18	4.0^{a}	8.0^{b}
	T. asperellum	7.1^{b}	7.1^{b}
	Azoxystrubin	3.3^{a}	3.3^{a}
	Iprovalicarb 5.5% +Propineb 25%	3.8^{a}	7.7^{b}
	Control	11.1^{c}	14.8^{c}
Cucumber	T 18	5.7^{ab}	7.5^{ab}
	T. asperellum	7.7^{b}	10.3^{b}
	Azoxystrubin	4.3^{a}	6.5^{a}
	Iprovalicarb 5.5% +Propineb 25%	4.2^{a}	6.3^{a}
	Control	11.3^{c}	15.1^{c}

Screening of Rice Genotypes for Disease incidence under Natural Condition

Seventeen landraces and three varieties of rice were screened for diseases and pest like False smut, Sheath rot, Brown spot and Stem borer under natural conditions. Response (reaction) to different diseases and pest were recorded based on 0-9 scale. Rajendra Mahsuri was found to be highly susceptible to false smut. Palia and Samayadhan were observed to be highly susceptible to stem borer. Reactions to different diseases/pest for different rice genotypes are provided in (Table 8.6).

Sixty two rice genotypes were evaluated for their reaction to sheath blight by artificial inoculation under natural conditions. For artificial inoculation *Rhizoctonia solani* were mass multiplied on Typha stem pieces. The plants were inoculated at maximum tillering stage (45-50 days after transplanting) with Patna isolate (*Rhizoctonia solani*) by placing the well colonized Typha stem pieces with the fungal myceliaum between tillers of each rice hills, just above the water level and tied for better contact with the sheath region. The water level

Table 8.6. Reactions to different diseases/pest for different rice genotypes

S No.	Genotypes	Disease reaction			
		FS	SR	BS	SB
1	Parwapankh	R	R	R	MS
2	Phuljaswa	R	R	R	MR
3	R.mahsuri	HS	MR	MR	MR
4	Rajshree	MS	R	R	MS
5	Ramdulari	MR	R	R	MR
6	Ramdulari-2	MR	R	R	MR
7	Sataria	MR	R	R	MS
8	Ujladhusari	R	R	R	S
9	Vaidehi	R	R	R	S
10	Varsadhan	MS	R	MR	MS
11	Barchha	MS	MR	MR	MR
12	Dhusari	MR	R	MR	MS
13	Harinkel	R	R	R	R
14	Jaswa	MR	R	R	MS
15	Jaswa-2	R	R	R	MS
16	Kusmser	R	R	R	MR
17	Laxmanbhag	R	R	R	MR
18	Palia	R	R	MS	HS
19	Samayadhan	MR	R	R	HS
20	Panjhhali	MR	R	MS	MS

FS: False smut; SR: Sheath Rot; BS: Brown Spot; SB: Stem borer; R: Resistant, MR: Moderately resistant; MS: Moderately Susceptible; S: Susceptible; HS: Highly Susceptible

(5-10cm) was maintained constantly for ensuring enough humidity to promote disease development. The lesion length and plant height were recorded 15 days interval. The relative lesion height (RLH) was calculated. Phuljaswa, Vaidehi, Barchha, Dhusari, Harinkel, Jaswa, Jaswa-2, Laxmanbhag, Samayadhan and Panjhhali were observed to the tolerant while Chandanchur-1, Kamod, Rajshree, Ramdulari, Ramdulari-2, Sataria, Ujladhusari, Varsadhan, Kusmser, Palia and Tulsiphul-1 were found to be moderately tolerant to sheath blight. However, further validation of these genotypes is required.

Disease reaction for Yard Long Bean Genotypes against Yellow Mosaic Disease

Forty Yard long bean (*Vigna unguiculata* ssp.) genotypes were screened against yellow mosaic disease in natural conditions (Fig. 8.18) RCPY-1, RCPY-2, RCPY-4, IC622601, LCM-5, IC626154 and IC626152 were found to be resistant. The detail disease reaction for all the genotypes is given in (Table 8.7).

Fig. 8.18 Yellow mosaic symptoms in susceptible genotype

Table 8.7. Disease reaction for yard long bean genotypes against Yellow Mosaic Disease.

S. N	Genotypes	Yellow Mosaic Disease	S. N	Genotypes	Yellow Mosaic Disease
1	YB-7	MS	21	IC626148	S
2	RCPY-2	R	22	IC626146	HS
3	RCPY-1	R	23	IC622579	S
4	RCPY-4	R	24	IC622597	HS
5	IC622601	R	25	IC626139	MR
6	LCM-5	R	26	IC626152	R
7	IC626154	R	27	IC626137	HS
8	IC630378	MS	28	IC630383	HS
9	IC630377	HS	29	IIHR-YLB	HS
10	IC622569	NP	30	IC626138	HS
11	LCK-2	HS	31	IC622599	S
12	IC626143	MR	32	IC626142	MR
13	LCM-2	MR	33	IC622598	S
14	IC622602	HS	34	IC626145	MR
15	IC626147	HS	35	IC630376	HS
16	IC622590	HS	36	IC626138 A	HS
17	IC626149	HS	37	IC630379	MR
18	LCM-1	HS	38	IC626140	MR
19	LCK-1	HS	39	IC622600	HS
20	IC626153	S	40	YB-7	NP

R: Resistant, MR: Moderately resistant; MS: Moderately Susceptible; S: Susceptible; HS: Highly Susceptible, NP: No plant

Mushroom

Collection, Identification and Conservation of Wild Edible Germplasm from Forest and Local Market of Jharkhand

Surveys were conducted at nearby forest area and local market of Ranchi, Simdega, Latehar, Palamu and

Garhwa district of Jharkhand during 2021. Three types of naturally grown wild edible mushrooms viz. Tecnus (*Termitomyces* species), Jamun khukhri (*Boletus edulis*) and Rugda (*Scleroderma* species) were found to be widely distributed and collected from Sal forest, local forest area and from local market of different district of Jharkhand. These wild edible mushrooms play an important role in improvement of rural livelihood. Among the wild edible mushroom, *Termitomyces* spp. and *Rugda* are sold in the market at a premium price @ Rs. 900-1000/kg (Fig. 8.19).

Advance varietal trial-2 of high yielding varieties/ strains of Oyster Mushroom (*Pleurotus* spp) on paddy straw substrates

Six high yielding strains of *Pleurotus* species (PL-20-201 to PL-20-206) were evaluated to study their yield performance in term of biological efficiency under Ranchi condition. Among the evaluated strains, the highest biological efficiency was recorded in PL-20-201 (66.4 %) which was statistically at par with PL-20-202 (63.6 %) and PL-20-206 (60.0 %) (Table 8.8 & Fig. 8.20).

Jamun Khukhri (*Boletus edulis*) *Termitomyces* species Rugda (*Scleroderma* species)

Fig. 8.19. Wild edible mushroom collected from the local market and neighboring forest of Ranchi

Table 8.8. Biological efficiency of advanced varietal trials of six strains of *Pleurotus* species (PL-20-201 to PL-20-206)

Strains of *Pleurotus* species	Yield parameters		
	Yield (kg/100kg dry straw)	Time taken for first harvest (days)	Average fruit body weight (g)
PL-20-201	66.4	28.4	12.6
PL-20-202	63.6	28.6	11.2
PL-20-203	58.6	30.6	11.7
PL-20-204	56.2	29.4	8.4
PL-20-205	51.4	28.8	9.7
PL-20-206	60.0	30.0	10.7
LSD (0.05)	6.5	NS	NS
C.V.	12.7		

PL-20-201 **PL-20-202** **PL-20-206**

Fig. 8.20. Biological efficiency of the advanced varietal trials of different strains of Pleurotus species at Ranchi, Jharkhand

9. Makhana

Effect of Seed Size on Productivity of Makhana and Size of Popped Makhana

Fourteen different sizes (grades) of makhana seeds were collected from the makhana fields. The weight of one seed had maximum size of 14.23 mm and mean weight of 1.36 g while the weight of the lowest size (7.34 mm) seed was of 0.24 g. There was a linear relationship between seed size and yield potential i.e., higher the size of seed higher was the yield. The pop size of the bigger size of seed was also higher as compared to lower size of the seed. But the correlation between the size of seed and size of pop was not linear, indicating that the any three consecutive size grades of makhana seed might yield almost equal size of makhana pop (Fig. 9.1-9.3).

Fig. 9.1. Fourteen grades of makhana seeds based on size

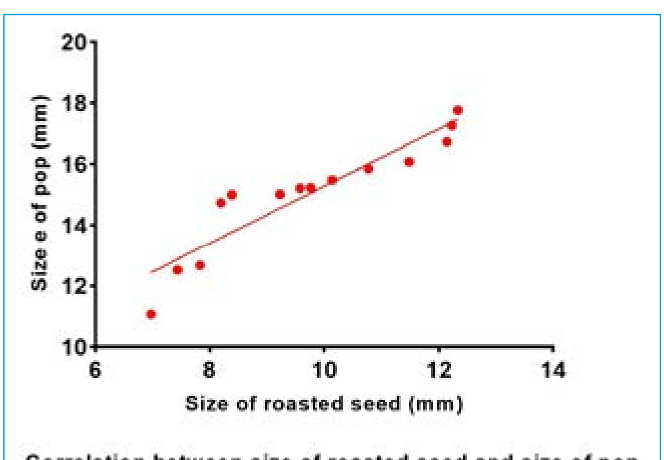


Fig. 9.2. Relation between size of roasted seed and size of makhana pop

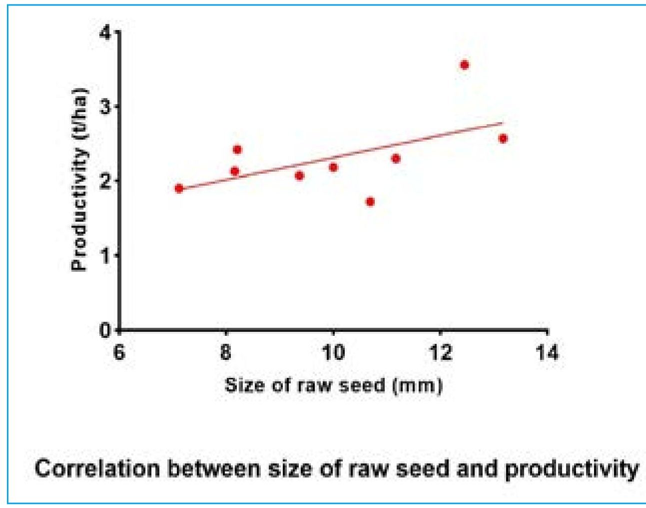


Fig. 9.3. Relation between size of seed and productivity of Makhana

Water chestnut

The high yielding germplasms of thornless fruit bearing red and green colour were distributed among the farmers of the Darbhanga, Madhubani and Sitamarhi districts of north Bihar. The raw yield potential of this variety was recorded at 10 to 11 t/ha. The productivity potential of high yielding thornless germplasm (10 t/ha) was 56.25% higher as compared to local thorny fruit bearing cultivar of water chestnut (6.4 t/ha).

Indian Lotus

It is a cross pollinated crop. The rhizome (root part) of the plant lies under the soil up to depth of 15-20 cm and shows horizontal expansion. The length of the rhizome varies from 0.50 m to 1.20 m consisting of two nodes in between (Fig. 9.4). One new plant emerges from one node, simultaneously, one flower bearing shoot also emerges from the same node. One leaf bearing stalk (length 40-70 cm), one flower bearing shoot (length 40-75 cm) and two new rhizomatic stems emerge from each nodal point of rhizomatic stem simultaneously (Fig. 9.5). The leaf of the plant had maximum expansion from north to south (i.e., 62 cm) and east to west (61 cm). The rhizome of the plant is made of aerenchyma tissues i.e., hollow from the inside. The fruiting was started in the last week of May could be harvested in the month of mid of October. One fruit had 15 to 16 sacs in which seed setting could take place; but only 2 to 4 numbers of seed formation could take place successfully (Fig. 9.6-9.7). The seed is elliptical in shape. The yield potential of the plant was recorded at 0.4 t/ha.

Growth parameters of Indian Lotus have been recorded.

(i) No. of leaves / m^2: 15 to 40 (Avg. 29)
(ii) No. of fruits / m^2: 10-15 (Avg. 7)
(iii) No. of seed pockets in one fruit: 10-20 (Avg. 12)
(iv) No. of seeds / fruit: 01-11 (Avg. 5)
(v) Wt. of 100 seeds: 98 g
(vi) Weight of one fruit: 20-40 g
(vii) Length of rhizome: 0.50-1.20 m
(viii) Leaf dimension: 45 x 52 cm

Effect of Secondary and Micronutrients on Yield and Quality of Makhana

To evaluate the impact of secondary and micro nutrients application on yield and quality of fox nut, a field experiment was conducted for two years at ICAR-RCER, RCM, Darbhanga with seven treatment combinations laid out in randomized complete block design with each treatment replicated thrice. Briefly, the treatments comprised of: T_1- control (no fertilization); T_2-100% NPK @100, 60 and 40 kg/ha applied through urea, DAP and MOP, respectively; T_3-NPK+Mg @ 5.0 kg/ha applied through $MgSO_4$; T_4-NPK+Zn@ 5.0 kg/ha applied through $ZnSO_4$; T_5-NPK+Cu@ 0.1% foliar spray with $CuSO_4$ solution; T_6-NPK+B @ 1.0 kg/ha applied through borax, and T_7-NPK+Mg+Zn+Cu+B, with the doses and sources as described in treatments T_2-T_6. Nutrient applications did improve the seed yield and quality of fox nut, though there were differential responses to primary (NPK), secondary (Mg) and micronutrients (Zn, B & Cu) applications. Sole application of NPK (T_2) improved seed yield by 26% over control (T_1). Application of Mg, Zn or B along with NPK (*i.e.* T_3, T_4 or T_6) caused further improvement of 46.4 – 49.7% over control and 16.2 – 18.9% over NPK application, with their yield boosting effects being statistically on par. Interestingly, foliar application of Cu combined with soil application of NPK (T_5) produced better result (62% yield increment over control and 28.5% over NPK) than the combination of any other nutrients with NPK. Foliar application of Cu proved to be 12 – 16% more effective than the soil application of Mg, Zn or B in terms of yield improvement. Combining all four nutrients with NPK (T_7) led to the best yield improvement in our study, which was 81% higher than the control and 43% higher than the sole NPK application (Table 9.1). In terms of relative yield, application of Mg, Zn, B or Cu along

Fig. 9.4. Lotus plants at vegetative growth

Fig. 9.5. Lotus plant at flowering stage

Fig. 9.6. Initiation of seed setting in flowers of lotus

Fig. 9.7. Section of rhizomes and bud bearing lotus plant

Table 9.1. Effect of nutrients' application on seed yield and yield parameters of fox nut

Treatments	Number of fruits/plant	Number of seeds/fruit	Seed Index (100 seed wt.) (g)	Seed yield (t/ha)
T_1 (Control)	7.33 [b]	55.3 [b]	73.2 [d]	1.81[e]
T_2 (NPK)	7.63 [ab]	59.1 [b]	84.6 [c]	2.28[d]
T_3 (NPK+ Mg)	7.78 [a]	66.3 [a]	93.1 [b]	2.65[c]
T_4 (NPK+ Zn)	7.76 [a]	67.2 [a]	92.6 [b]	2.71[c]
T_5 (NPK+ Cu)	7.86[a]	68.3 [a]	103.8 [a]	2.93[b]
T_6 (NPK+ B)	7.68 [a]	67.7 [a]	91.2 [b]	2.66[c]
T_7 (NPK+Mg+Zn+Cu+B)	7.82 [a]	71.3 [a]	109.5 [a]	3.27[a]
LSD (0.05)	0.41	5.3	6.2	0.21

with NPK increased the relative yield up to 1.46, 1.50, 1.47 and 1.62, respectively, compared to 1.0 at control, 1.26 with NPK, and 1.81 with combined application Mg, Zn, B and Cu along with NPK. Among the major yield determining plant parameters, seed index of fox nut followed nearly similar trends as that of seed yield in response to nutrients' application. Number of fruits per plant and seeds per fruit also increased with NPK, Mg and micronutrients application, but their effects could be separated with slightly lower level of statistical significance (p = 0.1).

Values within a column with common letter/s as superscript are not significantly different at P=0.05

Incidence of Aphid on Makhana and their Correlation with Weather Factors

In the aquatic crop Makhana (*Euryale ferox* Salisb.), *Rhopalosiphum nymphaeae* (Hemiptera: Aphididae) is the major aphid species widely distributed throughout its growing areas and pose severe threat to makhana in early stages of crop growing period.

The Aphid infestation starts from the December, when the left over Makhana seeds germinates and continues to the end of March and first week of April. The maximum population was observed during February and the population gradually decreased at the end of March. The correlation among pest incidence and weather factors revealed that Aphid infestation was negatively correlated with minimum and maximum temperature (Fig. 9.8), where correlation coefficient (r) values were -0.55 and -0.57, respectively. But aphid infestation was positively correlated with morning and evening relative humidity, where 'r' values were 0.53 and 0.64, respectively. Numbers of aphids were not significantly correlated with numbers of sunshine hours in a day.

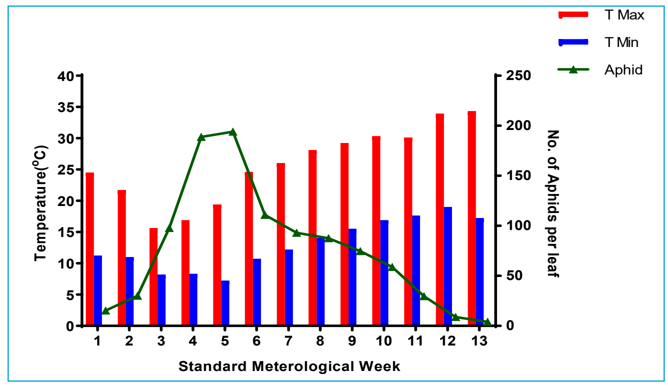


Fig. 9.8. Correlation between temperature and nos. of Aphids per leaf

Development of an Android Based Mobile Application "Makhana Guide"

Makhana Guide app was developed with an aim to help those who were interested in commercial makhana production, processing and value addition. It's a practical guide for the prospective farmers and processors, who can be benefitted by learning the technical know-how on every steps of makhana farming (including nursery raising, transplanting, nutrient management, crop protection and harvesting), post harvest processing and value addition. Compared to other traditional field crops grown in India, makhana farming is remunerative The app is also available in Hindi version as "Makhana Gyan". Both can be downloaded from Google play store for free (Fig. 9.9).

Fig. 9.9. The logo of 'Makhana Guide' App

10. Medicinal and Aromatic Plants

Performance Evaluation of Medicinal-Aromatic Plants in Eastern Indo Gangetic Plains

Adaptability studies of collected medicinal and aromatic plants:

Forty medicinal and aromatic plants were evaluated for their adoptability in Patna condition. Except few, majority of the plants were free from disease and pest. The most severe insect species was termite, which destroyed guggal and basil. Aphid was common for madhunasini, antamul and aswagandha. Like the previous year, root rot disease was observed in safed musli, and blight in *Hemigraphis* sp. Similarly alike previous year predatory spider (jumping spider) was observed in the basil plant from July end to October last week, 2021.

Evaluation of kulekhara for bioactive compounds and bioactivity:

Among various medicinal plants, *Hygrophila spinosa* (Kulekhara) was selected for detailed profiling of the phenolic compounds using ultra-performance liquid chromatography with quadruple time of flight mass spectrometry. A total of 14 compounds, including 4 flavonols, 2 phenolic acids, 5 flavone, 3 isoflavonoids were putatively identified based on high resolution accurate mass analysis with the data processing through UNIFI®, which is a comprehensive compound identification software solution. An in-house developed database comprising the secondary metabolites of phenolic compounds was used for the screening purpose, and each phenolic compound was identified based on the detection of the precursor ion and at least one characteristic fragment ion, each with less than 5 ppm of mass error. Flavones were the most abundant type of phenolics exhibiting 84% of the total phenolics in kulekhara leaves. Apigenin-7-*O*-Glucouronide was single predominant compounds in kulekhara, exhibiting 39% of the total phenolic. All these compounds were reported for the first time. Based on the results, it can be reflected that this underutilised plant might act as a potential functional food for the management of many bacterial infections.

Preliminary investigation on candy making using *Curcuma amada*:

Curcuma amada were explored for candy making. As a process, rhizome was peeled followed by cutting into pieces. After that, the pieces rhizome were cooked with pressure cooker. Then entire material was cooked in sugar syrup for 30 minutes and left for one night. Next day the whole materials were sieved using a strainer and air dried separately. The developed materials had the following sensory quality: Colour-light brown, non sticky, texture-buttery, taste-sweet with flavourful after taste.

Standardization of hydroponic technology for horticultural crops

a) **Evaluation of germplasm of leafy vegetables suitable for hydroponics:** 102 germplasm of leafy mustard were evaluated for suitability of growing under hydroponics. A wide range of variation was observed with respect of fresh leafy yield, leafy morphology, plant morphology and earliness of bolting. Few unique germplasm with distinct leaf and plant morphology were identified (Fig.10.1). Similarly, 25 germplasm of coriander were evaluated for leafy purpose. A wide range of diversity was observed with respect of plant height, leaf yield, leaf morphology, plant morphology and days to bolting. In addition to this 20 germplasm of fennel and pigmented radish were evaluated for their yield and other economic characters. Few germplasm were identified in radish with respect to root quality such as crispiness and pigments.

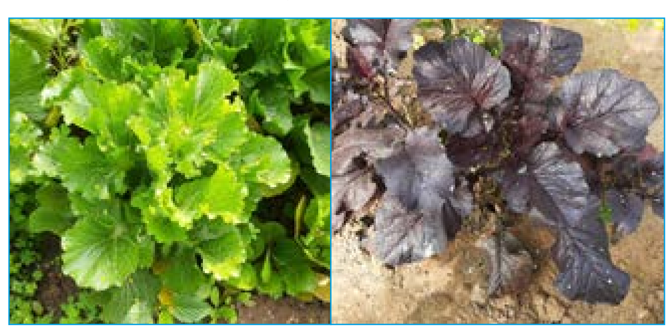


Fig. 10.1. Mustard germplasm suitable for cultivation under hydroponics

11. Farming System Research

Integrated Farming System

Resource recycling within the system

An experiment was conducted on resource cycling in two integrated farming system models viz. one acre area comprising of field crops + horticultural crops + goat + poultry + mushroom as midland irrigated system and in two-acre area comprising of field crops + horticultural crops + dairy + fishery, developed at research farm of the ICAR- Research Complex for Eastern Region, Patna. The field experiment was set up to study the resource recycling within the system, estimate the energy input-output, greenhouse gas emissions etc. for the different agricultural component.

Resource recycling in integrated farming system is one of the important activities through which resource use efficiency could be increased due to repeated use of wastes of different components within the system to increase nutrient use efficiency on one hand and also for decreasing the cost of cultivation and addition of organic forms of fertilizer to the system for its sustainability. Studies on nutrient recycling under one acre IFS model comprising of crops + goat + poultry as main components while mushroom and vermicomposting as supplementary components revealed a total waste production of 2.35 t of goat manure, 6.18t of vegetable wastes, 1.72 t of poultry droppings and 1.72t of rice/maize/lentil straws which were recycled within the system and added nitrogen (47.2 kg), phosphorus (36.8 kg) and potash (40.6kg) in the soil which was equivalent to 103.0kg urea, 230.0 kg SSP and 68.0 Kg of MOP (Table 11.1). In monetary terms, these recycled nutrients had saved a sum of Rs. 3,108/- in a year. In addition to these nutrients, an ample quantity of micronutrients was also added to the soil upon nutrient recycling of different wastes.

Likewise, two-acre IFS model comprised of crops+ livestock +fish/duck also produced 16.8 t of cow dung from two cows, 10.2 t of vegetable wastes, 2.22t of biomass from green manure crops and 1.10 t of duck dropping from 35 ducks during 2020-21 and upon recycling of these wastes into the systems, nitrogen (68.6 kg), phosphorus (52.7 kg) and potash 44.7 kg were added into the soil which is equivalent to 149.0 kg urea, 329.8 kg SSP and 74.5 kg of MOP. In monetary terms, these recycled nutrients had saved a sum of Rs. 4,297/- with respect to chemical fertilizer (Table 11.2).

Table 11.1. Nutrient recycling pattern under two-acre IFS model (Crops + fish + livestock)

Farm waste	Quantity produced (t)	Production/ use pattern (t)	Nutrient gain (kg)	Nutrient gain upon recycling	Saving through recycling (Rs.)	Fertilizer saving (kg)
Goat (20+ 1) droppings	2.35	1.72 (GM- 0.9) 0.63 (VC)	N- 15.3 P- 10.8 K- 14.6	N- 47.2 P- 36.8 K- 40.6	Rs. 3,108/-	103.0 kg urea 230.0 kg SSP 68.0 kg MOP
Vegetable waste	6.18	2.12 (VC- 0.83) 4.06- As fodder	N- 12.4 P- 10.2 K- 13.4			
				Note: Urea@ Rs. 5.40/kg SSP @ Rs. 7.25/kg MOP @ Rs. 16.0/kg		
Poultry manure (700)	1.72	0.72 Total quantity used in crops	N- 16.3 P- 13.5 K- 10.6			
RWMML Straw + Cowpea	4.62 + 0.72	0.6 – Mushroom 1.25- Mulching 2.62- Dairy farm 0.72- turning up	N- 3.2 P- 2.3 K- 1.8			

Table 11.2. Nutrient recycling pattern under two-acre IFS model (Crops + fish + livestock)

Farm waste	Quantity produced (t)	Production/ use pattern (t)	Nutrient gain (kg)	Nutrient gain from recycling	Saving (Rs.)	Fert. equivalent (kg)
Cow dung (2 +2 calf)	16.8	FYM- 10.4) 2.0 (VC) 4.0- Pond	N-20.7 P- 20.2 K-12.3	N=68.6 P=52.7 K=44.7	Total: Rs. 4,297/-	149 kg urea 329.8 kg SSP 74.5 kg MOP
Veg. waste	10.2	5.0 (VC-2.1) 5.2 As fodder	N- 31.5 P- 21.1 K- 22.6			
Duck drop. (35)	1.10	As fish feed/silt	N- 8.4 P- 6.2 K- 5.6	Note: Urea@ Rs. 5.40/kg SSP @ Rs. 7.25/kg MOP @ Rs. 16.0/kg		
Dhaincha/ Moong	2.22t	Incorporated in the soil	N- 8.0 P- 5.2 K- 4.4			

Green House Gas emission from IFS models

In another study on greenhouse gas (GHG) emission from both the models, it was found that C- sink was greater than C- source in both the models which indicates that the developed IFS models are emitting lesser greenhouse gases. In one acre IFS model, Poultry component has emitted highest GHGs (542.5 kg CO_2-e) and was followed by goat unit (396.9 kg CO_2 -e) whereas livestock unit under two-acre IFS model has emitted higher GHG (1552.3 kg CO_2-e) followed by fish-cum-duck unit (828.0 kg CO_2 -e).

From this study, it can be concluded that animal/bird component emits more GHGs over other components under the study viz. field crops, mushroom, fishery and horticulture etc. Further, the net GHG emission was found negative for both the developed IFS models (-1457.6 kg CO2 -e and -2670.0 kg CO2 -e, respectively) which advocates that the developed IFS models are environmentally safe and one or two more suitable components with less GHG emission capacity may be added based on need and requirement. The detail emission of GHGs from different components in both the models have been presented in (Table 11.3).

Table 11.3. Net emission of GHG from different components of IFS models

C- source	Enterprises	CO_2-e (kg) (One acre)	CO_2-e (Kg) (Two acre)
Cropping System			
CS1	Rice-wheat	84.9	145.6
CS2	Rice-maize	59.3	130.1
CS3	Rice-lentil	44.1	111.7
CS4	Rice-linseed	50.8	98.3
Other components	Fruit-Veg. crops	128.2	69.6
	Paddy-special	75.6	151.2
	Goat/Livestock	396.9	1552.3
	Poultry/Duck	542.5	204.5
	Kitchen garden	170.8	178.7
	Pond- Fishery	0.0	628.0
Carbon- sink	Agro-Forestry- SINK	1378.6	3439.0
	Biomass/compost added	1632.2	2500.9
	Total C- SOURCE	1553.2	3270.1
	Total C-SINK	3010.8	5940.1
	GHG-IFS	-1457.6	-2670.0

Development of Location Specific Integrated Farming System Models for Rainfed Ecosystem of Eastern Plateau and Hill Region

An IFS model (crop + horticulture + dairy) has been developed with the objective to ensure food security of a family under rainfed ecosystem. In the model, livestock (2 cow + 2 calves), fruits (guava and badhal) have been integrated with cereals, pulses and oilseeds. During 2021, one acre rainfed area was found sufficient for fulfilling the daily dietary requirement of a family. The one acre area yielded 180.0 kg guava, 1027.8 l. milk, 157.1 kg pulses, 670.1 kg cereals, 73.9 kg oil from oilseeds and 357.1 kg vegetables (Table 11.4). The area allotment was also calculated under different components during *rabi* and *kharif*. It was found that during *kharif* maximum area was devoted for cultivation of cereals (38%) followed by pulses (30.6%) (Fig. 11.1). In *rabi* season, maximum area was allotted under pulses (48.1%) followed by oilseeds (25.5%). The total manure production was recorded as 4.8 t/year and cow urine production was recorded as 3752 l/year from two cow and two calves. The total green fodder production was 4.7 t/year.

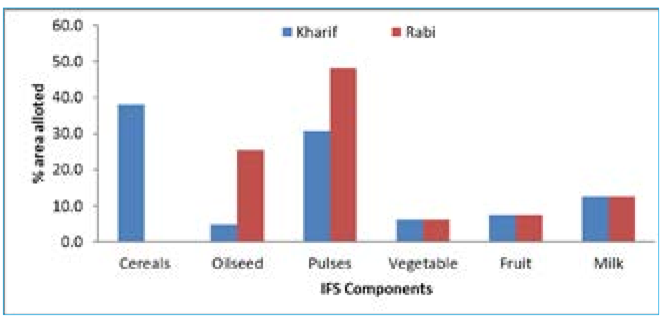


Fig. 11.1 Percent area allotment under different components during *rabi* and *kharif* in one acre

Optimization techniques for enhancing profitability in IFS

Optimization technique using linear programming, lpsolve algorithm in 'R' software, was used to optimize land allocation in IFS model for maximum net return. Four components such as crop, horticulture, livestock, and fish components were taken in this model. Objective function was the net income of farmers from an IFS model which contained decision variables. The optimized value of net income was calculated as $Z_{NI} = \Sigma (Y_i A_i (R_i - C_i)$; where, Y_i = yield of i^{th} component in q/ha, A_i = area of i^{th} crop in ha, R_i = market price of i^{th} crop in Rupees/q and C_i = cost of cultivation in Rupees/q. In this model, the constraints were land, labour, outside purchase and cost of recycled waste within the system, which saved the cost of input due to recycling of waste from one component to another component and increased income and resource use efficiency.

Constraints:

Constraint 1: $A_C + A_H + A_L + A_F \leq 2$ (acre)

Constraint 2: $A_C \geq 1$ acre (50% of total area)

Constraint 3: $A_H \geq 0.3$ acre (15% of total area)

Constraint 4: $A_L \geq 0.04$ acre (2% of total area)

Constraint 5: $A_F \geq 0.3$ acre (15% total area)

Constraint 6: $L_C + L_H + L_L + L_F \leq$ TLM (total labour man-days)

Constraint 7: $3200 A_C + 23333 A_H + 200000 A_L + 4516 A_F \leq 32000$ (TOP: total outside purchase)

Constraint 8: $3100 A_C + 16666 A_H + 325000 A_L + 6290 A_F \leq 40000$ (RWS: recycled within the system)

Ground water utilization in different components of IFS

Total water availability in one year 7.8 ha-m or 19.5 acre-m

Constraint 9: $0.5 A_C + 0.3 A_H + 1.35 A_F + 0.009 A_L \leq 19.5$ (TWA)

Constraint 10: $43 A_C + 150 A_H + 2875 A_L + 73 A_F \leq 240$ (labour man-days)

where, I_C, I_H, I_L and I_F are the net income from crop, horticultural crop, livestock and fish. Ac: area under cereal crops, A_H: area under horticultural crops, A_L: area under livestock, A_F: area under fish, L_C: manpower required for crop (in man-days), L_H: manpower required

Table 11.4. Daily dietary requirement fulfilled from IFS system (1 Acre) under rainfed condition .

IFS Components	Component wise Area (m^2)		Production from one acre (kg)	Req. of a family (kg)	Deficit(-)/surplus (+) (kg)
	Kharif	Rabi			
Cereals	1520	0	670.1	438.0	232.1
Oilseed	200	1020	73.9	43.8	30.1
Pulses	1225	1925	157.1	104.0	53.1
Vegetable	250	250	357.1	328.5	28.6
Fruit	300	300	180.0	146.0	34.0
Dairy unit (Cow + fodder)	505	505	1027.8 lit. milk	584.0 lit. milk	443.8 lit.

in horticulture, L_L: manpower required in livestock, L_F: manpower required in fish cultivation, C_O: outside input purchased for cereal crops, H_O: outside input purchased for horticultural crops, L_O: outside input purchased for livestock, F_O: outside input purchased for fish, C_R: recycled waste in cereal crops, H_R: recycled waste in horticultural crops, L_R: recycled waste for livestock, F_R: recycled waste for fish

This problem was solved by employing lpsolve algorithm through R programming for the existing area allocated under different activities and results are reported in (Table 11.5).

Results showed that gross income, input cost and net income was Rs.325065, 193240 and 131825, respectively. After optimization of land allocation to different components, the gross income, input cost and net income was analysed as Rs. 450020, 287990 and 162030, respectively (Table 11.6).

It may be noted that income increased by Rs.30250 (23%) in two acre model of IFS after optimized reallocation of land among different components. Soil health also remained in good condition due to resource recycling among different components and ultimately resource use efficiency also increased.

Evaluation of Zero Budget Natural Farming (ZBNF) for Eastern Plateau and Hill Region

The experiment was undertaken to evaluate the Zero Budget Natural Farming module for different cropping systems in EPHR in terms of crop productivity, soil fertility, plant protection, nutritional quality, system productivity and economic viability with conventional and ZBNF as main plots and crops in sub plots in split plot design. It was laid out in two blocks in isolation. In *kharif*, paddy, black gram, finger millet and cow pea were evaluated whereas in *rabi*, lentil, niger, mustard and chick pea were evaluated.

The cropping patterns of Paddy-Lentil, Black gram-Niger, Finger millet- Mustard & Cow pea- Chick pea were evaluated. The desi varieties of lentil, mustard, niger and chick pea were taken. The four principles of ZBNF *i.e.,* seed treatment by *Beejamrita*, *Ghan Jeevamrita*, *Jeevamrita*, paddy straw as mulch to suppress weeds and *Whaapasa* for moisture conservation technique were applied. For plant protection measure, application of *Neemastra*, *Agniastra* and *Brahmastra* were followed.

The microbial count of initial soil samples from the experimental site has been depicted in (Table 11.7 and Fig. 11.2).

Growth and Yield Attributes:

The growth and yield attributes of conventional and ZBNF as plant height, seed test weight, yield, straw yield, biological yield and harvest index were recorded and has been depicted in Table 11.8. The plant height at 90 days after sowing was higher in conventional farming as compared to ZBNF. The cow pea, black gram, paddy and finger millet recorded plant height of 91.35 cm, 71.75 cm, 116.50 cm and 93.50 cm in CF whereas in ZBNF it

Table 11.5. Two Acre model data from Anantpur village, Nalanda

Variables	Crop	Horticulture	Livestock	Fish	Constraints
Land (acre)	1.36	0.3	0.04	0.3	≤ 2
Labour (mandays)	58	45	115	22	≤ 240
Outside purchase (Rs.)	4000	7000	16000	2000	≤ 32000
Recycled within the system (Rs.)	3500	5000	26000	3500	≤ 40000
Gross income (Rs.)	59425	78650	118320	68670	325065
Total input cost (Rs.)	34970	44645	78750	34875	193240
Net income (Rs.)	24455	34005	39570	33795	131825

Table 11.6. Optimized area and income from different components of IFS (Anantpur village, Nalanda)

Components	Optimized land area (Acre)	Total input cost (Rs.)	Optimized gross income (Rs.)	Optimized net income (Rs.)
Crop	1	25800	50290	24490
Horticulture	0.5	74400	120800	46400
Livestock	0.07	137800	186500	48700
Fish	0.43	49990	92430	42440
Total	2.0	287990	450020	162030

Table 11.7. Summary of the 16s rRNA sequencing data of Microbiota associated with initial soil samples

ZBNF Plots	No. of bacterial reads	Pre-processed consensus sequences	Total consensus sequences	No. of observed OTUs*	GC content (%)	Avg. length (nt)
ZBNF-R1	156466	1425	1386	183	58.08	250
ZBNF-R2	224290	188116	85195	5346	58.3	250
ZBNF-R3	197077	164363	79483	4382	58.82	250
Total	577833	353904	166064	8392		

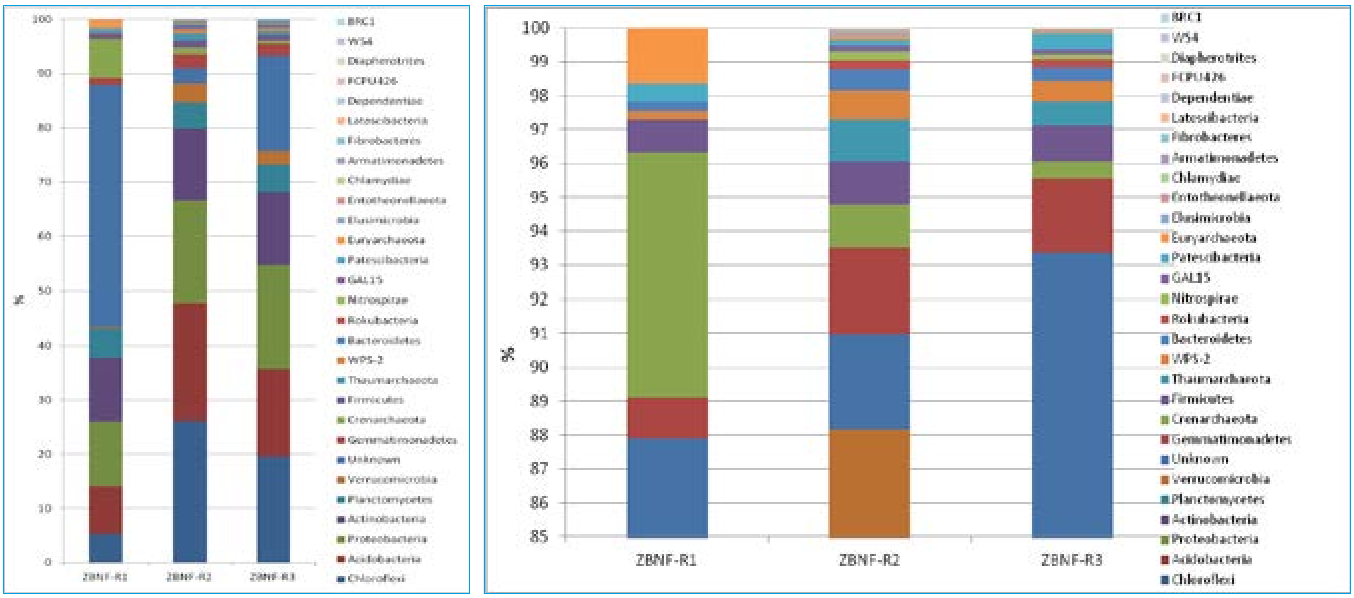


Fig. 11.2. Microbiota associated with Initial Soil sample of experimental Site

Table 11.8. Growth & yield attributes of ZBNF & CF k*harif* crops in 2020

Treatment	Plant height (cm)	Seed test weight (g)	Yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	Harvest Index
ZBNF						
Cow pea	84.6	17.0	62.06	22.23	88.68	74.94
Black gram	59.5	4.35	7.81	17.38	25.20	30.54
Paddy	92.5	3.07	13.87	21.05	34.92	39.71
Finger millet	90.7	0.26	19.41	38.95	58.36	33.27
Conventional Farming						
Cow pea	91.35	16.37	52.06	19.87	71.93	72.43
Black gram	71.75	4.17	11.06	15.90	26.96	40.96
Paddy	116.5	3.00	22.35	33.57	55.92	40.03
Finger millet	93.50	0.21	8.95	26.85	35.80	24.83
CD 5%	12.81	0.83	5.64	38.00	55.16	5.62

was recorded at 84.60 cm, 59.50 cm, 92.50 cm and 90.70 cm, respectively. The zero budget natural farming gave comparatively higher yield of cowpea (62.06 q/ha) and finger millet (19.4 q/ha) than the conventional farming (52.06 q/ha and 8.95 q/ha, respectively). However, the yield of paddy (22.35 q/ha) and black gram (11.06 q/ha) was recorded higher in conventional farming as compared to the zero budget natural farming (13.87 q/ha and 7.81 q/ha, respectively). Similarly, straw yield, seed test weight, biological yield and harvest index was recorded higher in cow pea and finger millet in ZBNF in comparison to conventional farming. However, in case of paddy and black gram, straw yield, seed test weight, biological yield and harvest index was recorded higher in conventional farming in comparison to the ZBNF.

The growth and yield attributes of *rabi* season crop under conventional and ZBNF are depicted in (Table

11.9-11.10 and Fig. 11.3.) The plant height of lentil and chick pea at 90 days after sowing was higher in ZBNF (28.50 cm and 36.50 cm, respectively) as compared to conventional farming. However, in mustard and niger, conventional farming recorded higher plant height (96.40 cm and 47.47 cm, respectively) as compared to ZBNF (81.15 cm and 47.0 cm, respectively). Similarly, the canopy spread was found higher in ZBNF. Root length, shoot length, shoot weight, grain yield per plant, number of pods per plant and number of branches per plant were also found higher in ZBNF in comparison to CF. The seed test weight was found higher in all crops in CF in comparison to ZBNF except chick pea. The ZBNF methods of lentil, niger and chick pea showed higher seed yield whereas CF grown mustard showed higher seed yield in comparison to ZBNF.

Table 11.9. Growth & yield attributes of ZBNF & CF Rabi crops

Treatment	Plant height (cm)90 DAS	Canopy spread (cm^2) 90 DAS	Root length (cm)	Shoot weight (g/Plant)	Grain yield (g/plant)	Number of Pods/plant	Number of branches /plant
ZBNF							
Lentil	28.25	281.5	7.8	3.709	1.015	23.9	23.05
Nizer	47.00	361.1	7.8	3.57	2.478	18.85	7.1
Mustard	81.15	262.6	9.3	4.795	2.79	53.8	5.45
Chickpea	36.50	521.95	9.5	6.751	4.813	19.2	11.9
Conventional Farming							
Lentil	23.73	227.97	5.7	2.848	0.71	17.00	13.15
Nizer	47.47	197.95	6.925	2.612	1.01	15.72	6.963
Mustard	96.40	215.90	7.75	4.551	1.65	45.10	4.55
Chickpea	28.70	285.15	8.20	6.497	2.71	22.67	11.55
CD 5%	7.725	36.67	1.979	3.28	1.76	11.05	5.084

Table 11.10. Yield attributes of ZBNF & CF *rabi* crops

Treatment	Test weight (g)	Seed yield (g/plot)	Straw yield (g/plot)	Seed yield (q/ha)	Straw yield (q/ha)	Biological yield (Kg/ha)	Harvest Index (%)
ZBNF							
Lentil	1.243	180.0	1600	0.90	8.00	8.9	10.21
Nizer	0.153	215.0	775	1.07	3.88	4.95	22.49
Mustard	0.245	220.0	600	1.10	3.00	4.10	27.04
Chickpea	18.10	387.5	625	1.93	3.12	5.06	38.09
Conventional Farming							
Lentil	2.18	150.0	1000	0.75	5.0	5.75	13.47
Nizer	0.17	202.5	962.5	1.01	4.81	5.82	17.42
Mustard	0.36	270.0	750.0	1.35	3.75	5.1	23.87
Chickpea	17.63	155.0	251.7	0.775	1.26	2.03	38.32
CD 5%	7.725	18.801	39.16	0.94	1.957	2.78	5.63


Jivamrita application in ZBNF Paddy


Jivamrita application in ZBNF Nizer


Cowpea under ZBNF plots

Fig. 11.3. Field view of experiment under ZBNF and conventional farming at FSHR

12. Crop Diversification

Evaluation of Establishment Methods for Improving the Productivity of Rice Fallows

A long-term field study was initiated since the rainy season of 2016 at ICAR-RCER Patna to find out the most suitable rice–winter crop rotations; and appropriate crop establishment methods and residue management practices in rice–fallow system in eastern India. Treatments comprised of six levels of crop establishment methods-cum-residue management (CERM) practices: zero–till direct seeded rice (ZTDSR), conventional-till-DSR (CTDSR), puddle transplanted rice (PTR), ZTDSR with rice residue retention (ZTDSRR+), CTDSR with rice residue retention (CTDSRR+), PTR with rice residue retention (PTRR+) and five post–rainy season crops *viz.* chickpea (Pusa 256), lentil (HUL 57), mustard (Proagro 5111), linseed (T 397) and safflower (PBNS 12) fitted in a split–plot design. Results revealed that rice yields were noted higher in general after pulses-based cropping system . Rice productivity was 32.2 and 19.1% were higher in PTR (5.18 t/ha) compared to ZTDSR (3.92 t/ha) and CTDSR (4.35 t/ha) irrespective of residue management. It was found more interestingly that yield of all the post-rainy crop was higher under ZTDSR/CTDSR compared to TPR production system (Table 12.1).

Efficacy of Different Sources of Nitrogen and Zinc on Forage Sorghum Yield

A field experiment was carried out in split plot design during *Kharif* 2021 to evaluate the efficacy of different nitrogen and zinc sources on forage sorghum yield. Three nitrogen management strategies *i.e.*, N_1: Whole recommended dose of nitrogen (RDN) through inorganic fertilizer (IN), N_2:75% RDN (IN) + Four foliar spray of Nano-N (1.08 ml/l) and N_3: 50% RDN (IN) + Five foliar spray of Nano-N (1.74 ml/l) were taken as main plot treatments while three zinc management strategies Viz., Zn_0: Control (No Zn), Zn_1: Zinc @ 10 kg/ha (IN) and Zn_2: 5 kg Zinc (IN) as basal + Four foliar spray of Nano-Zn (0.5 ml/l) were assessed in subplots with three replications. A general view of treatment effect at 50 days after sowing (DAS) is shown in (Fig. 12.1).

Table 12.1. Rice yield as influenced by different crop establishment-cum-residues management practices and succeeding crops (Mean data of 2021)

CERM	Rice yield (t/ha)	Winter crop yield (t/ha)				
		Chickpea	Lentil	Safflower	Linseed	Mustard
[ZTDSR-ZT] R-	3.79^{F}	1.77^{B}	1.76^{B}	1.63^{B}	1.07^{C}	1.56^{C}
[ZTDSR-ZT] R+	4.04^{E}	2.01^{A}	1.99^{A}	1.87^{A}	1.27^{A}	1.75^{A}
[CTDSR-ZT] R-	4.19^{D}	1.54^{C}	1.51^{C}	1.26^{D}	0.98^{DE}	1.47^{E}
[CTDSR-ZT] R+	4.50^{C}	1.76^{B}	1.73^{B}	1.45^{C}	1.16^{B}	1.65^{B}
[TPR-ZT] R-	5.00^{B}	1.34^{D}	1.29^{D}	1.14^{E}	0.93^{E}	1.37^{F}
[TPR-ZT] R+	5.35^{A}	1.52^{C}	1.47^{C}	1.26^{D}	1.04^{CD}	1.51^{D}
Mean		1.66	1.63	1.43	1.08	1.55

Fig. 12.1. View of growth of Sorghum forage at 50 DAS

Application of N_2 + Zn_1 (39.41 t/ha) followed by N_2 + Zn_2 (37.81 t/ha) showed significantly higher green forage yield at first cut over rest of the treatment combinations. However, at second cut the combination of N_1+Zn_2 (27.60 t/ha) was at par with N_1+Zn_1 (26.14 t/ha), N_2+Zn_2 (25.73 t/ha) and N_2+Zn_1 (25.67 t/ha) which was significantly higher as compared to remaining N and Zn management strategies. Further, interaction effect of N_2+Zn_1 (65.08 t/ha) was also at par with N_2+Zn_2 (63.54 t/ha), N_1+Zn_2 (62.75 t/ha) and N_2+Zn_0 (62.61 t/ha) but showed higher total green forage yield as compared to rest of the treatments.

Fig. 12.2. Performance of nutri-cereals under different planting windows at RCER, Patna

Standardization of Agro-Techniques in Nutri-Cereals for Enhancing the Productivity in Eastern India

A long-term field experiment was initiated during *Kharif* 2020 at ICAR-RCER, Patna with an objective of designing most productive, profitable, and sustainable climate resilient cropping system for eastern India. Seven nutri-cereals including jowar (CSV 15) and bajra (Proagro 9001) and 5-minor nutri-cereals [i.e., ragi (RAU 8), barnyard millet (VC 207), foxtail millet (Rajendra Kauni), proso millet (TNAU 202) and kodo millet (JK 41)] were grown under 3-different planting window i.e., starting with onset of monsoon (05 July 2021) and later at 10-days intervals (15 July and 25 July 2021). Results revealed that 2nd planting window (15 July 2021) performed better as compared to II & III planting window system (05 July & 25 July 2021) in terms of crop yield (Table 12.2 and Fig. 12.2). Among nutri-cereals, jowar (3427 kg/ha) and bajra (2887 kg/ha) as major and barnyard millets (2060 kg/ha), ragi (1925 kg/ha) and kodo millet (2045 kg/ha) as minor nutri-cereals were found more productive when planted with 2nd planting window i.e., 15th July 2021. Based on the local preferences, bajra and ragi among major millets, & barnyard among minor nutri-cereals has been identified for further agronomic study.

Diversification of Rice-Wheat Cropping System with Vegetables

An experiment was conducted to identify the most suitable diversified rice based cropping system for silty clay loam soil at ICAR-RCER, Patna. Rice was cultivated as *kharif* crop followed by vegetables and wheat as *rabi* crops and greengram as summer crop. Six cropping systems i.e. rice-wheat-green gram, rice-potato-greengram, rice-tomato- greengram, rice-cauliflower-greengram, rice-broccoli- greengram and rice-garden pea- greengram were studied with short (Swarna Shreya) and long duration (MTU 7029) Swarna rice varieties. Among six cropping systems rice-wheat cropping system was treated as control and other diversified cropping systems were compared with the control treatment.

Rice crop duration significantly influenced the yield of *rabi* crops and system productivity as a whole. Rice variety Swarna Shreya attained maturity in 119 days while variety Swarna (MTU 7029) took 28 more days than Swarna Shreya. *Rabi* crops grown after medium duration rice produced significantly higher yield with better quality than those grown after long duration rice variety. During *kharif* season Swarna produced 28 per cent higher yield than Swarna Shreya (5.29 t/ha) but yield of *rabi* and summer crop were significantly lower than those grown after Swarna (Table 12.3). Crop diversification

Table 12.2.Yield of nutri-cereals in different planting windows system (Mean data of 2021)

Nutri-cereals	Grain yield (t/ha)		
	1st Planting (05 July 2021)	2nd Planting (15 July 2021)	3rd Planting (25 July 2021)
Sorghum (CSV-15)	2.75	3.43	2.91
Bajra (Proagro-9001)	2.21	2.89	2.29
Foxtail millet (Rajendra Kauni)	1.39	1.74	1.52
Barnyard millet (VC 207)	1.67	2.07	1.72
Proso millet (TNAU 202)	0.66	0.86	0.59
Finger millet/Ragi (RAU 8)	1.50	1.93	1.59
Kodo millet (JK 41)	1.75	2.05	1.82

Table 12.3. Effect of rice varieties and diversified cropping system on yield and rice equivalent yield (t/ha)

Treatments	Rice yield (t/ha)	Rabi yield (t/ha)	Greengram yield (t/ha)	REY of rabi crop (t/ha)	REY of greengram (t/ha)	System REY (t/ha)
Rice						
Swarna Shreya (medium duration)	5.29	24.90	0.95	15.42	3.40	22.54
Swarna (long duration)	6.76	10.50	0.48	7.18	1.73	14.32
C.D (P=0.05)	0.16	0.51	0.11	1.24	0.39	2.05
Cropping System						
R-W-GG	6.01	4.01	0.63	4.41	2.26	12.68
R-P-GG	6.03	20.75	0.76	8.03	2.72	16.78
R-T-GG	5.98	20.88	0.62	13.47	2.23	21.68
R-CF-GG	6.04	32.35	0.72	18.43	2.57	27.04
R-Br-GG	6.01	20.54	0.74	15.90	2.64	24.55
R-GP-GG	6.09	6.08	0.83	3.92	2.97	12.98
C.D (P=0.05)	NS	2.02	NS	1.34	NS	1.71

also showed significant differences among different cropping systems with respect to yield. Irrespective of rice varieties, the system productivity of rice-cauliflower-greengram (27.04 t/ha) was significantly superior over other cropping systems followed by rice-broccoli-greengram (24.55 t/ha). Cauliflower and broccoli grown after Swarna Shreya provided an opportunity to introduce one more crop in the system before sowing of greengram due to which the cropping intensity was increased. Hence, spinach and spring onion were sown after cauliflower and broccoli, respectively which further enhanced the system productivity of respective cropping system. Significant differences were also observed within the system due to duration of rice crop. After third crop cycle nutrient status of different cropping system varied from each other but no significant differences were found due to variation in rice crop duration. Rice-garden pea-greengram showed highest available nitrogen (216.53 kg/ha) and available phosphorous (28.58 kg/ha) among other diversified cropping systems (Table 12.4).

Further, economics of different cropping systems was also affected due to diversification of cropping system as well as variation in rice crop duration (Table 12.5). Rice-cauliflower - spinach -green gram produced significantly higher rice equivalent yield (34.80 t/ha), net return (Rs. 3,07,326) and benefit : cost ratio (2.43) among all cropping systems followed by rice- - broccoli - spring onion -greengram (net return: Rs. 2,65,730 & B:C : 2.23) and rice-tomato-greengram (net return: Rs. 1,93,636 & B:C : 2.14).

Table 12.4. Rice equivalent yield and economics as influenced by cropping system and rice duration

Cropping Systems	REY (t/ha)	Gross income (Rs/ha.)	Cost of cultivation (Rs/ha.)	Net return (Rs/ha)	B:C ratio
Short duration rice					
Rice-Wheat-Greengram	13.92	208845	129336	79509	1.61
Rice- Potato -Greengram	19.44	291645	170036	121609	1.72
Rice- Tomato -Greengram	24.19	362850	169214	193636	2.14
Rice-C.F-Spinach - Greengram	34.80	521955	214629	307326	2.43
Rice-Broccoli-Sp. onion - Greengram	32.15	482250	216520	265730	2.23
Rice-Pea-Greengram	14.11	211650	120067	91583	1.76
Long duration rice					
Rice-Wheat-Greengram	11.45	171750	131000	40750	1.31
Rice- Potato -Greengram	14.12	211845	171084	40761	1.24
Rice- Tomato -Greengram	19.17	287550	172912	147638	1.66
Rice-Cauliflower- Greengram	19.29	289305	171558	120747	1.69
Rice-Broccoli- Greengram	16.95	254205	173050	78858	1.47
Rice-Pea-Greengram	11.85	177700	119805	57895	1.48

Diversification of Existing Upland Production Systems with Tuber Crops in Eastern Plateau and Hill Region

Under rainfed upland condition of Eastern Plateau and Hill region, the trial on diversification of direct sown upland rice and finger millet with tuber crops like colocasia and sweet potato was conducted during *kharif* and *rabi* season of 2020-21 (Fig. 12.3). Rice, finger millet, colocasia and sweet potato were grown as sole crops. The plot size was 50m^2. The sale prices of rice, finger millet, colocasia and sweet potato were Rs.18.68, Rs.32.95, Rs.20.0 and Rs.30 per kg, respectively. The sole crop of sweet potato recorded the maximum rice equivalent yield of 14.02 t/ha followed by that of colocasia (7.46 t/ha) and finger millet (5.96 t/ha). The sole crop of rice recorded yield 2.37 t/ha only. The energy productivity was maximum in sweet potato (0.9 kg/Mj) compared to rice (0.29 kg/Mj) and finger millet (0.83 kg/Mj). The BC ratio of colocasia (3.46) was maximum followed by that of sweet potato (2.36), finger millet (2.14) and rice (1.63). So, diversification of rainfed upland rice production system with tuber crops like colocasia and sweet potato would be more profitable in Eastern Plateau and Hill Region.

Fig. 12.3. Diversification of rainfed upland production system with tuber crops

Studies on Weed Seed Bank Dynamics in Different Cropping Systems in The Middle Indo-Gangetic Plains (IGP)

Studies on weed seed bank dynamics and weed diversity in 12 cropping systems was undertaken during *rabi* 2020-21 and *kharif* 2021. From the studies, it was found that lower soil layer 10-20 cm depth recorded higher weed count (21.4/m^2) as compared to surface soil i.e., 0-10 cm (12.7/m^2) except in horticulture-based cropping systems where upper soil layer (0-10 cm) recorded higher weed count as compared to field crops. Rice-mustard- greengram & rice-lentil- greengram (51.0/m^2) recorded maximum weed infestations per unit area whereas, horticulture-based production systems were heavily infested at 0-10 cm of soil depth (52.6/m^2) than that of other cropping systems in *rabi* season (Fig. 12.4).

Further, it was found that broad leaved weed (BLWs) was the dominant weed flora in all the cropping system during rabi season. The major dicot weeds observed were *Chenopodium album, Solanum nigrum, Medicago denticulata, Cichorium intybus and Anagallis arvensis* etc. while major monocot weeds were *Cynodon dactylon*, *Cyperus rotundus, and Polypogon monspeliensis* etc.

Fig. 12.4. Experiment on weed seed bank dynamics

Table 12.5. Effect of diversified cropping system on fertility status of soil

Cropping Systems	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	MBC (µg C g^{-1} soils)	Urease (µg urea $^{g-1}$ soil $^{h-1}$)	BD (Mg m^{-3})
Short duration rice	228.372	27.214	154.458	85.189	322.194	1.48
Long duration rice	174.876	23.373	153.783	74.477	265.25	1.45
C.D.at5%	4.82	NS	NS	4.84	13.96	NS
Cropping systems						
Rice-Wheat-Greengram	190.252	22.598	140.698	78.788	247.718	1.49
Rice-Tomato-Greengram	197.645	24.847	130.758	80.478	290.108	1.48
Rice-Potato-Greengram	208.557	24.415	145.772	75.182	285.322	1.45
Rice-C.F-Spinach -GG	196.892	25.427	160.495	78.127	293.102	1.45
Rice-Broccoli-Sp. onion -GG	199.862	25.897	181.48	79.058	303.468	1.49
Rice-Pea-Greengram	216.532	28.58	165.52	87.367	342.613	1.44

During *kharif* season, rice was taken in the cropping system, lower soil layer i. e. 10-20 cm depth recorded lesser weed count (23.68/m^2) compared to surface soil i. e. 0-10 cm (31.6/m^2) while all other cropping systems followed the same trend as *rabi* season in respect of weed seed bank (Table 12.6). Further, it was observed that monocot weeds such as *Cyperus rotundus*, *Cynodon dactylon, Echinocloa colona*, *Alternanthera sessilis* etc. are the dominant weed flora in all the cropping system during *kharif* season under the study.

Network Project on Conservation of Lac Insect Genetic Resources

A survey work was conducted to assess the availability of naturally occurring lac insect and its host plants for future promotion of lac cultivation in the region as a subsidiary occupation in Bihar for the benefit of farming community. In continuation to survey for natural occurrence of lac insect and its host plants in Bihar during the year 2021, survey was conducted in 10 districts covering 54 blocks. Lac insects were found in 15 blocks of 4 districts only. Thus, out of 244 blocks of 38 districts surveyed in Bihar since 2019, only 75 blocks of 22 districts found to be harbouring lac insect in varied proportion mostly on *Ficus religiosa*, *Ficus benghalensis* and rarely on *Ziziphus mauritiana* (Patna and Kaimur) *and Butea monosperma* (Banka, Nawada). Majority of insects were found dead, but at a few places, good live population was noticed. Invariably southern districts of Bihar showed rich diversity in naturally surviving lac insects (Fig. 12.5-12.7). I*n situ* conservation of local lac insects at four locations in Patna district namely Sipara and Parsa (Patna Rural block), Punpun (Punpun block) and Taregna (Masaurhi block) is being carried out and observed two species of predators namely, *Eublemma amabilis*, *Pseudohypatopa pulverea* and two species of primary parasitoids *viz.*, *Tachardiaephagus tachardiae* and *Aprostocetus purpureus* were dominant with lac insect whereas other reported predators and parasitoids were meager in number. Among the parasitoids, *A. purpureus* was more in number (42 per 10 cm lac encrustation) as compared to *T. tachardiae* (14 per 10 cm lac encrustation).

Table 12.6. Impact of cropping systems on weed seed dynamics (Mean data of *kharif*, 2021)

Cropping Systems	0 -10 cm			10-20 cm		
	Total	Monocot	Dicot	Total	Monocot	Dicot
Rice- Wheat	5.2 (22.2)	21.4	0.8	5.79 (28.6)	26.8	1.8
Rice- Maize	4.82 (18.3)	15.3	3.0	6.26 (34.2)	30.4	3.8
Rice- Mustard- Greengram	5.14 (21.5)	20.4	1.1	7.17 (46.5)	42.2	4.3
Rice-Lentil- Greengram	4.95 (18.6)	16.5	2.1	6.91 (42.8)	40.9	1.9
Guava + Turmeric	5.50 (25.2)	16.8	8.4	5.19 (22.0)	15.2	6.8
Lemon +Turmeric	6.28 (34.4)	26.3	8.1	4.85 (20.5)	13.6	6.9
Cowpea- Tomato- Okra	4.85 (18.5)	15.6	2.9	5.58 (26.2)	18.6	7.6
Okra- Cauliflower-onion	4.53 (23.0)	11.8	11.2	5.5 (25.3)	20.1	5.2
Rice- Cauliflower - Greengram	4.09 (28.2)	27.0	1.2	3.16 (15.5)	15.5	0
Jowar- Chickpea- Fallow	5.76 (16.5)	12.8	3.7	6.10 (32.2)	25.8	6.4
Cowpea (F)-Jowar (F)-Berseem	5.1 (20.2)	14.3	5.9	5.45 (24.8)	19.3	5.5
Maize (F)-Cowpea (F)-Oat (F)	5.80 (28.6)	18.8	9.8	5.94(30.4)	23.4	7.0
CD (*P*:0.05)	0.31	-	-	0.22	-	-

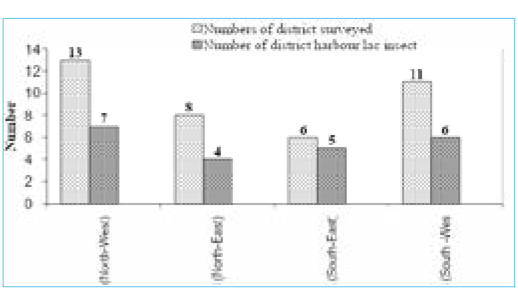


Fig. 12.5. Zone wise natural occurrence of lac insect in Bihar

Fig. 12.6. Natural occurance of lac on *F. benghalensis*

Fig. 12.7. Natural occurance of lac on *F. religiosa*

13. Carbon Sequestration and Nutrient Dynamics

Optimizing Soil Organic Carbon Stock in Rice-Based Cropping System in Irrigated Ecosystem

A field experiment (for the first season) was initiated at ICAR-RCER farm during *rabi* 2020-21. Three crops viz Lentil (HUL 57), Chickpea (Pusa 256) and Mustard (RH 749) were sown. The yield under different treatments is shown in (Fig. 13.1). Crop under sprinkler irrigation showed higher biomass and yield than drip, flood and control irrigation systems. Test weight also showed similar trend (Table 13.1) where yield in sprinkler and drip irrigation was higher by 9.64 and 15.09% compared to no irrigation (Fig. 13.2).

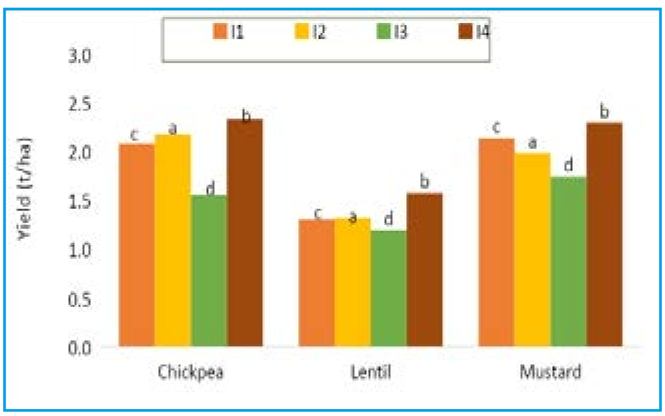


Fig. 13.1. Yield of chickpea, lentil and mustard under different irrigation systems (I1: Surface; irrigation I2: Sprinkler irrigation; I3: No irrigation; I4: Drip irrigation)

Table 13.1 Test weight of crops under different irrigation treatments during *rabi* season of 2020-21

Treatments	Chickpea	Lentil	Mustard
Surface irrigation	25.90	15.91	5.07
Sprinkler irrigation	26.15	17.07	5.11
No irrigation	23.85	15.00	4.68
Drip irrigation	27.45	17.61	5.19
Average	25.90	15.91	5.07
LSD (0.05)	1.32	0.86	0.54

Developing Precision Nutrient Management Protocols for Rice-Wheat and Rice-Maize Systems in Indo-Gangetic Plains

Field experiments on "Calibration and validation of nitrogen requirement using android based application" for maize and rice were implemented during 2020-21 (*rabi* season) and 2021 (*kharif* season) at the experimental farm of ICAR Research Complex for Eastern Region, Patna to evaluate the effect of different doses of nitrogen (N) and varieties (V) on growth, yield parameter of rice, and N content of leaf at different growth stages of rice and maize. The treatments were as follows: 1) N0: No nitrogen; 2) N40: 40 kg N; 3) N80: 80 kg N; 4) N120: 120 kg N; 5) N160: 160 kg N; 6) N200: 200 kg N and 7) N240: 240 kg N was added. Maize varieties were: TM 214; 2) S2 946; 3) S2 981; 4) 2ATM211 and 5) 2ATM214 and *Rice* varieties were: 1)

Fig. 13.2. Field view under different irrigation methods

Swarna Shreya; 2) Swarna Samridhi dhan; 3) Swarna Shakti; 4) Swarna Sukha Dhan and 5) RCPR 58.

Twenty five days old rice seedlings were transplanted on 13-07-2020. Full doses of phosphorus (60 kg/ha) and potassium (60 kg/ha) were applied after puddling (before transplanting). Moreover, the preceding crops were wheat in winter and fallow during summer. N was applied at three equal splits. The first dose of N (1/3) was applied as basal during seeding/transplantation. The remaining two splits were applied at the knee height stage and tusseling for maize and at maximum tillering and PI stages for rice.

For developing strategies on precision N management, an android based application was developed based on leaf colour, canopy development. Field experiments were conducted on rice and maize with different cultivars and nitrogen doses for gathering input data required during the development of a model for predicting the amount of nutrients required at a particular point of time. For that purpose, leaf colour, canopy development and other related parameters were monitored at a particular time interval (10-15 days).

Yield data of maize was compared among different nitrogen doses and genotypes (Fig. 13.3). Irrespective of genotypes, the lowest and highest yield was noted for N80 and N240 treatments, respectively. A positive relation was obtained between grain yield and N application (R^2 = 0.59) (Fig. 13.4) and the empirical relation suggests an increase of ~20 kg yield for application of each kilogram of nitrogen. However, the yield of maize was determined at 59 DAT and it was found that the yield was plateaued after 160 kg/ha N and therefore, 160 kg N ha^{-1} could be the most optimal dose for maximal profitability.

The effect of nitrogen on rice yield was clearly discernible (Fig. 13.5). Irrespective of rice genotypes,

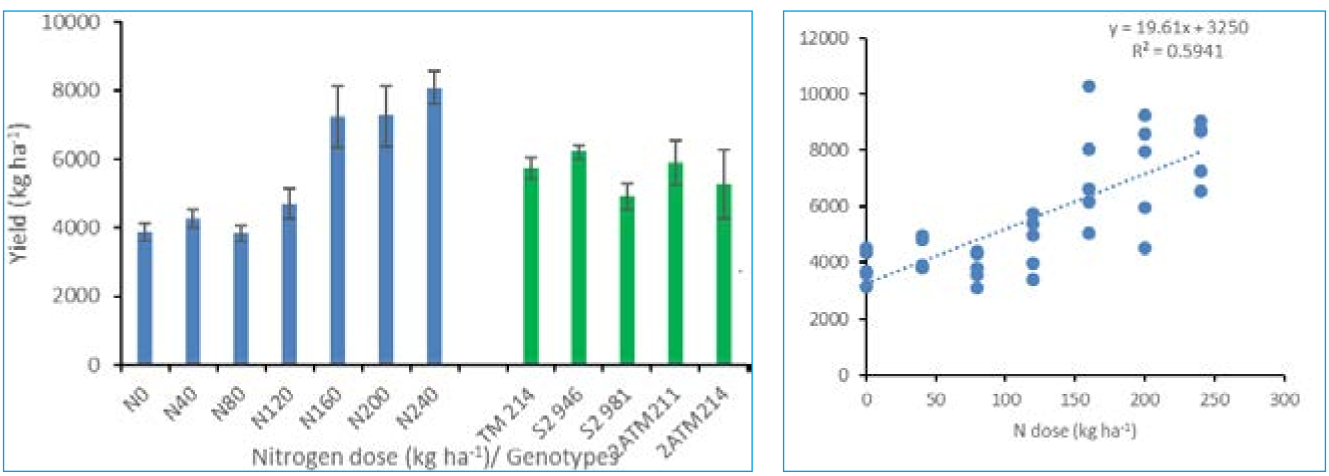


Fig. 13.3. Yield of maize as affected by different N-doses and genotypes and relationship between N-dose and yield. Vertical bars represent ±SE of the mean

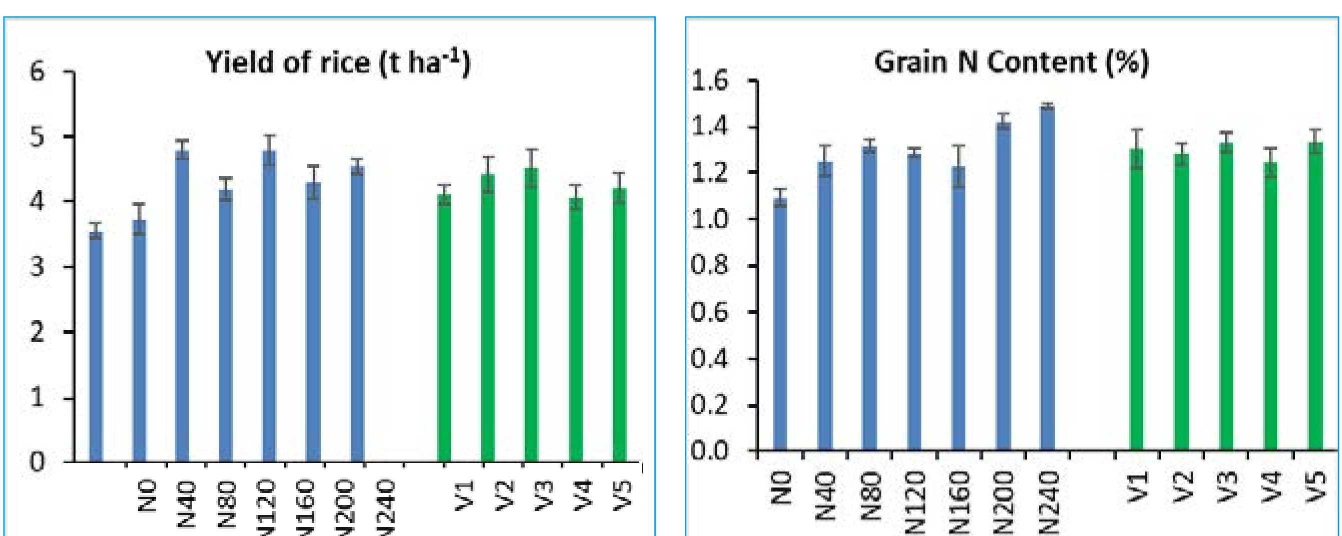


Fig. 13.4 Yield of rice and grain nitrogen content (%) as affected by different N-doses and genotypes

Fig. 13.5. Experiment on effect of nitrogen on rice yield

the maximum grain yield of 4.8 t/ha was noted by N80 and N160. Overall, an increasing trend in grain yield was observed with increase in fertilizer N up to 160 kg/ha but decreased thereafter. The least grain yield was noted under control (3.6 t/ha). Among the rice genotypes, Swarna Samridhi and Swarna Shakti performed better than others. For grain N content, an increasing trend was noted for different N doses.

Evaluation of leaching loss of nutrients in acidic soils of Jharkhand under different cropping systems

Leaching loss of nitrogen in tomato

Fertilizer management practices showed significant effect (P<0.001) on the quantity of N leached from lysimeters. The control treatment (T1: no NPK) recorded uniform leaching loss of available N throughout the crop growth period of 125 days during cropping seasons of 2020-21 (Fig. 13.6). When 100% RDF was applied as inorganic (T2), the available N leaching loss increased slowly as the cropping season progressed to 89 days after transplanting, thereafter it declined and attained uniform rate at each irrigation event. The T_2 treatments, wherein entire fertilizer was applied through inorganic sources, showed higher N-leaching loss, due to the increased mineralization flush of nitrogen with the progress of crop growth. The N-leaching loss from 100% RDF as organic (T3) was very low, which could be attributed to the stimulation of microbial growth in the soil by organic N-sources leading to temporary immobilization of N in the microbial biomass. The treatment receiving 50% RDF as inorganic + 50% RDF as organic (T4) also called an intergrated nutrient management (INM) recorded gradual increase in leaching loss of available N upto 96 days after transplanting. The T_4 treatment, where both organic and inorganic source of fertilizer might have resulted in comparatively slow mineralization of N throughout the crop growth period and caused extended period of lower and steady leaching loss

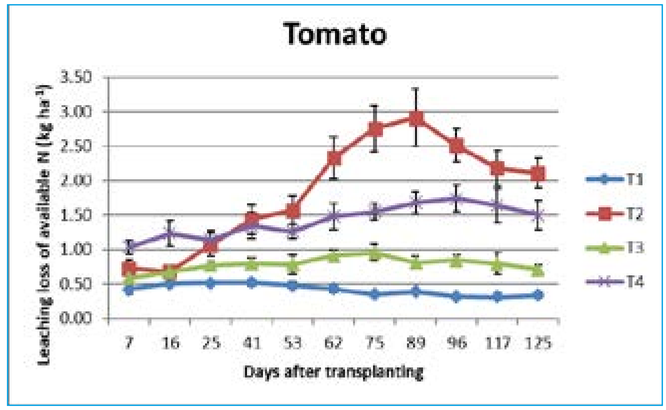


Fig. 13.6. Leaching loss of nitrogen in tomato at different days after transplanting. T1: N0-P0-K0 (Control); T2: 100% RDF as inorganic; T3: 100% RDF as organic; T4: 50% RDF as inorganic +50% RDF as organic

Leaching loss of nitrogen in pea

The leaching loss of N in T1 and T3 was steady and uniform throughout the crop growth period. The average single event N-leaching loss in T1 was 0.36 kg/ha while in T3 it was 0.46 kg/ha during 2019-20, respectively (Fig. 13.7). The N-leaching loss in control treatment (T1) was attributed to the mineral-N content of the soil along with the mineralization of the N-fixed by the pea crops during the crop growth period. Furthermore, the N-leaching in organic treatment (T3) was slightly higher than control could be attributed to the lower N-mineralized from organic manure, as they were incorporated prior to the period when leaching rate was measured. The N-leaching loss in T2 recorded gradual increase upto 53 days after sowing and thereafter the N-loss declined and attained steady state. The average single event N-leaching loss in T2 was 0.76 kg/ha during 2019-20. Similarly, the T4 recorded gradual increase in N-leaching loss up to 53 days after sowing. In this treatment, the average single event N-leaching loss was 0.58 kg/ha.

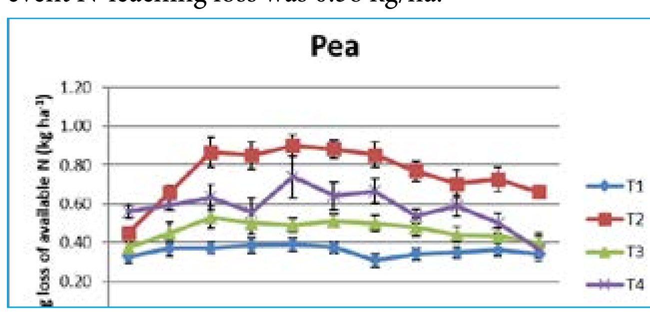


Fig. 13.7. Leaching loss of nitrogen in pea crop at different days after transplanting.

Leaching loss of potassium in tomato

The K-leaching loss in T1 was uniform throughout the crop growth period of 125 days (Fig. 13.8). Potassium leaching in organic treatment (T3) was slightly higher than T1. In T3 treatment, the peak K loss was observed between 25-89 days with average single event loss of 0.55 kg/ha. The K-leaching loss in T2 was highest throughout the crop growth period with average single event loss of 1.28 kg/ha. Similarly, T4 recorded slow and steady increase of K-leaching loss up to 53 days after transplanting with average loss of 0.95 kg/ha in each single leaching event. The results confirmed that there was an increase in K leaching loss in the beginning of the crop growth period, which was attributed to the higher flow of water mostly controlled by macropores followed by steady and almost constant K-losses was controlled by matrix flow.

Leaching loss of potassium in pea

The K-leaching loss in T1 was gradual and steady

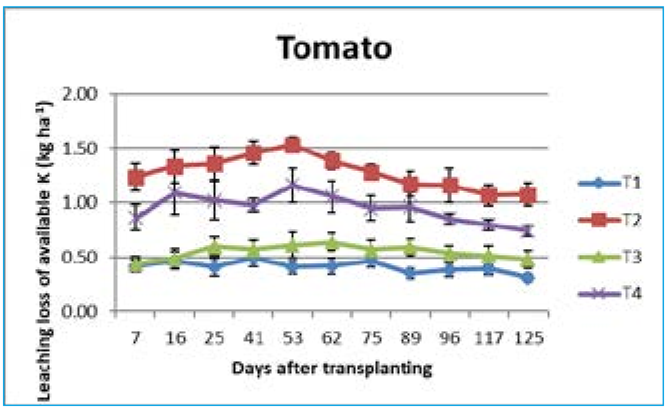


Fig. 13.8. Leaching loss of potassium in tomato at different days after transplanting.

throughout the investigation period with average loss of 0.48 kg/ha in each single leaching event (Fig. 13.9). The inorganic treatment (T2) showed gradual increase in K-leaching loss upto 62 days and thereafter the loss gradually declined. The average K-leaching loss in T2 was 0.93 kg/h[a] in each single leaching event. The organic treatment (T3) recorded slightly higher leaching loss compared to T1 with average leaching loss of 0.61 kg/ha in each single leaching event. The INM treatment (T4) observed lower average leaching loss of 0.81 kg/ha compared to T_2. The treatments T2 and T4, where inorganic fertilizer was applied, extended the peak of K-leaching loss, which was attributed to higher root CEC of legume resulting in higher affinity for divalent cations and less affinity for cation exchange with K, being the monovalent.

Nutrient balance sheet in okra

The nutrient balance sheet of okra showed that the actual balance of available N in soil was negative compared

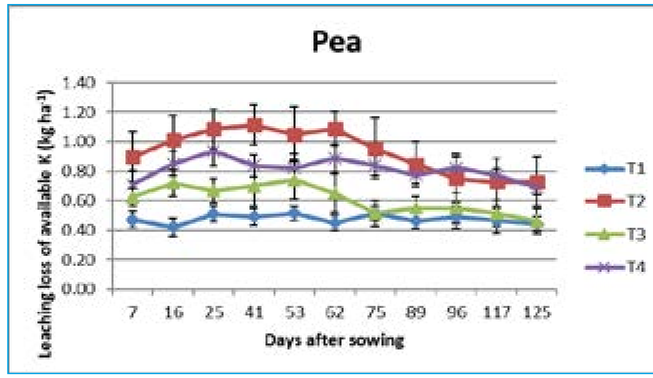


Fig. 13.9. Leaching loss of potassium in pea at different days after transplanting.

to the initial value in all the treatments. The higher negative N balance was -33.9 kg/ha in the control plot (T1) and the least negative N balance was -20.3 kg/ha in the treatment receiving 100% recommended NPK as organic manure (T3). The uptake of N by the okra crop varied from 31.0 to 57.7 kg/ha among the different treatments. The available P balance in soil also showed negative value in all the treatments except T3 which showed positive balance of 0.8 kg/ha. The P-uptake varied from 8 to 10 kg/ha. The expected P-balance showed higher negative value in the treated plots was due to the fixation of applied fertilizer to the soil compared to control (No addition of fertilizer). The available K balance showed negative value and varied from -24.3 to -76.9 kg/ha, being highest in control. The K-uptake in okra crop was highest of 82.1 kg/ha in T4 treatment.

Nutrient balance sheet in green gram

The available N balance sheet in greengram showed negative balance in all the treatments except T4 treatment which showed positive N balance of 2.1 kg/ha (Table 13.2-13.4). The highest negative N balance of 10.1 kg/ha was recorded in the treatments T2. The N-uptake by green gram crop was highest of 47.8 kg/ha in T4 treatment and was followed by T2 (46.1 kg/ha). The expected balance of N showed positive value in all the treatments due to N-fixation by the green gram. The available P balance sheet in green gram showed positive value varied from 1.0 to 14.6 kg/ha. The highest P balance was 14.6 observed in the T3 treatment followed by T4. The P-uptake by green gram crop varied from 4.1 to 6.2 kg/ha. The available K balance sheet in green gram showed negative value in all the treatments except in T3, which showed highest K balance of 19 kg/ha. The K-uptake by green gram crop varied from 17.9 to 27.2 kg/ha among the different treatments, being highest in T2 and T4 treatments.

Nutrient balance sheet in rice

The nutrient balance sheet of *kharif* rice showed that the actual balance of available N in soil was negative compared to the initial value in all the treatments. The higher negative N balance was -40.0 kg/ha in the inorganic plot (T2) and the least negative N balance was -15.8 kg/ha in the organic treatment (T3). The uptake of N by the rice crop varied from 24.3 to 51.9 kg/ha among the different treatments. The available P balance in soil showed positive balance in organic (T3) treatment having 6.6 kg/ha.The p-uptake varied from 4.7 to 10.3 kg/ha. The available K balance showed negative value and varied from -20 to -57 kg/ha, being highest in control. The K-uptake in rice crop was highest of 46 kg/ha in T2 treatment.

Nutrient balance sheet in finger millet

The available N balance sheet in finger millet showed negative balance in all the treatments and varied from 13.2 to 52.6 kg/ha (Table 13.5-13.7). The highest negative N balance of -52.6 kg/ha was recorded in the treatments T1. The N-uptake by finger millet was highest of 58 kg/ha in T4 treatment and was followed by T2 (54.6 kg/ha). The available P balance sheet in finger millet showed negative value varied from -10.0 to -16.4 kg/ha. The highest negative P balance was -16.4 kg/ha observed in the T2 treatment. The P-uptake by finger millet varied from 12.0 to 29.6 kg/ha. The available K balance sheet in finger millet showed negative value in all the treatments, being highest in T2 (-52.4 kg/ha). The K-uptake by finger millet varied from 33.5 to 62.0 kg/ha among the different treatments, being highest in T4.

Table 13.2. Effect of nutrient management on N-balance sheet in summer okra and green gram

Treatment	Initial status (kg/ha)	Nutrient added (kg/ha)	Crop uptake (kg/ha)	Leaching loss (kg/ha)	Expected availability in soil (kg/ha)	Actual availability in soil (kg/ha)	Expected balance (kg/ha)	Actual balance (kg/ha)
	A	B	C	D	E=(A+B)-(C+D)	F	G=F-E	H=F-A
Okra								
Control	172.3	0	31.0	1.6	139.6	138.4	-1.2	-33.9
Inorganic	192.3	120	49.5	11.2	251.6	166.0	-85.6	-26.3
Organic	184	120	43.5	3.4	257.1	163.7	-93.4	-20.3
INM	179.4	120	57.7	7.9	233.8	157.3	-76.5	-22.1
Greengram								
Control	168.8	0	24.2	2.716	141.9	166.0	24.12	-2.8
Inorganic	180.6	25	46.1	5.348	154.1	170.5	16.38	-10.1
Organic	184	25	43.5	3.532	161.9	180.5	18.55	-3.5
INM	171.4	25	47.8	4.301	144.3	173.5	29.18	2.1

Table 13.3. Effect of nutrient management on P-balance sheet in summer okra and green gram

Treatment	Initial status (kg/ha)	Nutrient added (kg/ha)	Crop uptake (kg/ha)	Leaching loss (kg/ha)	Expected availability in soil (kg/ha)	Actual availability in soil (kg/ha)	Expected balance (kg/ha)	Actual balance (kg/ha)
	A	B	C	D	E=(A+B)-(C+D)	F	G=F-E	H=F-A
Okra								
Control	22.2	0	7.9	0.0005	14.3	12.5	-1.8	-9.7
Inorganic	34.8	25	9.6	0.0074	50.2	33.5	-16.7	-1.3
Organic	30.9	25	8.9	0.0007	47.0	31.7	-15.3	0.8
INM	33.3	25	10.1	0.0037	48.2	30.4	-17.9	-2.9
Green gram								
Control	25.3	0	4.1	0.0008	21.2	26.3	5.0	1.0
Inorganic	36.8	50	5.6	0.0093	81.2	44.8	-36.3	8.0
Organic	33.6	50	5.8	0.0036	77.8	48.2	-29.6	14.6
INM	35.4	50	6.2	0.0083	79.2	46.0	-33.1	10.6

Table 13.4. Effect of nutrient management on K-balance sheet in summer okra and green gram

Treatment	Initial status (kg/ha)	Nutrient added (kg/ha)	Crop uptake (kg/ha)	Leaching loss (kg/ha)	Expected availability in soil (kg/ha)	Actual availability in soil (kg/ha)	Expected balance (kg/ha)	Actual balance (kg/ha)
	A	B	C	D	E=(A+B)-(C+D)	F	G=F-E	H=F-A
Okra								
Control	203.6	0	70.5	1.896	131.2	126.7	-4.5	-76.9
Inorganic	238.9	50	72.9	6.515	209.5	208.9	-0.6	-30
Organic	235.8	50	79.3	3.165	203.4	211.5	8.1	-24.3
INM	233.3	50	82.1	4.589	196.6	181.6	-15.0	-51.7
Green gram								
Control	191.6	0	17.9	1.7	172.0	165.7	-6.3	-25.9
Inorganic	223.4	25	27.2	4.3	216.9	202.4	-14.5	-21
Organic	220.8	25	26.3	2.0	217.4	239.8	22.4	19
INM	222.3	25	27.2	3.4	216.8	213.4	-3.4	-8.9

Table 13.5. Effect of nutrient management on N-balance sheet in *kharif* rice and finger millet

Treatment	Initial status (kg/ha)	Nutrient added (kg/ha)	Crop uptake (kg/ha)	Leaching loss (kg/ha)	Expected availability in soil (kg/ha)	Actual availability in soil (kg/ha)	Expected balance (kg/ha)	Actual balance (kg/ha)
	A	B	C	D	E=(A+B)-(C+D)	F	G=F-E	H=F-A
Rice								
T1	200.0	0	24.3	10.43	165.3	163.1	-2.2	-36.9
T2	243.4	40	51.7	20.2	211.5	203.4	-8.1	-40.0
T3	230.8	40	41.2	11.48	218.1	215.0	-3.1	-15.8
T4	252.3	40	51.9	16.2	224.2	229.4	5.2	-22.9
Finger millet								
T1	187.0	0	34.1	10.13	142.8	134.4	-8.4	-52.6
T2	227.5	33	54.6	14.23	191.7	188.2	-3.6	-39.4
T3	210.2	33	51.0	10.93	181.3	197.0	15.7	-13.2
T4	235.0	33	58.0	12.4	197.6	215.7	18.1	-19.3

Table 13.6. Effect of nutrient management on P-balance sheet in *kharif* rice and finger millet

Treatment	Initial status (kg/ha)	Nutrient added (kg/ha)	Crop uptake (kg/ha)	Leaching loss (kg/ha)	Expected availability in soil (kg/ha)	Actual availability in soil (kg/ha)	Expected balance (kg/ha)	Actual balance (kg/ha)
	A	B	C	D	E=(A+B)-(C+D)	F	G=F-E	H=F-A
Rice								
T1	22.1	0	4.7	0.071	17.3	11.6	-5.7	-10.5
T2	39.3	20	9.4	0.113	49.8	30.2	-19.6	-9.1
T3	30.8	20	8.6	0.077	42.1	32.1	-10.0	1.3
T4	32.5	20	10.3	0.1	42.1	30.1	-12.0	-2.4
Finger millet								
T1	26.3	0	12.0	0.067	14.2	13.2	-1.0	-13.1
T2	44.8	13	26.2	0.092	31.5	28.4	-3.1	-16.4
T3	42.1	13	27.2	0.077	27.8	32.1	4.3	-10.0
T4	46.0	13	29.6	0.088	29.4	34.6	5.2	-11.4

Table 13.7. Effect of nutrient management on K-balance sheet in *kharif* rice and finger millet

Treatment	Initial status (kg/ha)	Nutrient added (kg/ha)	Crop uptake (kg/ha)	Leaching loss (kg/ha)	Expected availability in soil (kg/ha)	Actual availability in soil (kg/ha)	Expected balance (kg/ha)	Actual balance (kg/ha)
	A	B	C	D	E=(A+B)-(C+D)	F	G=F-E	H=F-A
Rice								
Control	175.8	0	30.2	7.1	138.5	118.7	-19.8	-57.1
Inorganic	237.8	20	46.1	12.12	199.6	187.3	-12.3	-50.5
Organic	221.5	20	35.5	7.96	198.1	201.6	3.5	-19.9
INM	241.3	20	44.9	10.1	206.3	211.0	4.7	-30.3
Finger millet								
Control	160.7	0	33.5	5.04	122.1	112.8	-9.3	-47.9
Inorganic	243.4	17	58.0	8.38	194.0	191.0	-3.0	-52.4
Organic	219.2	17	54.0	5.5	176.7	200.4	23.7	-18.8
INM	231.3	17	62.0	7.2	179.1	204.2	25.1	-27.1

Ferti Solver - A Decision Support Tool for Fertilizer Management

Site specific nutrient management involving soil test-based application of fertilizers is critical to enhance fertilizer use efficiency. With increasing laboratories and awareness among farmers, soil testing is becoming a routine practice. Adjustment of recommended doses of fertilizers in accordance with the soil test reports is still a challenge. The 'FertiSolver' tool has been developed to address these challenges and help the farmers in achieving higher productivities with reduced cost on fertilizer through balanced and optimal doses of fertilizers (Fig. 13.10-13.11).

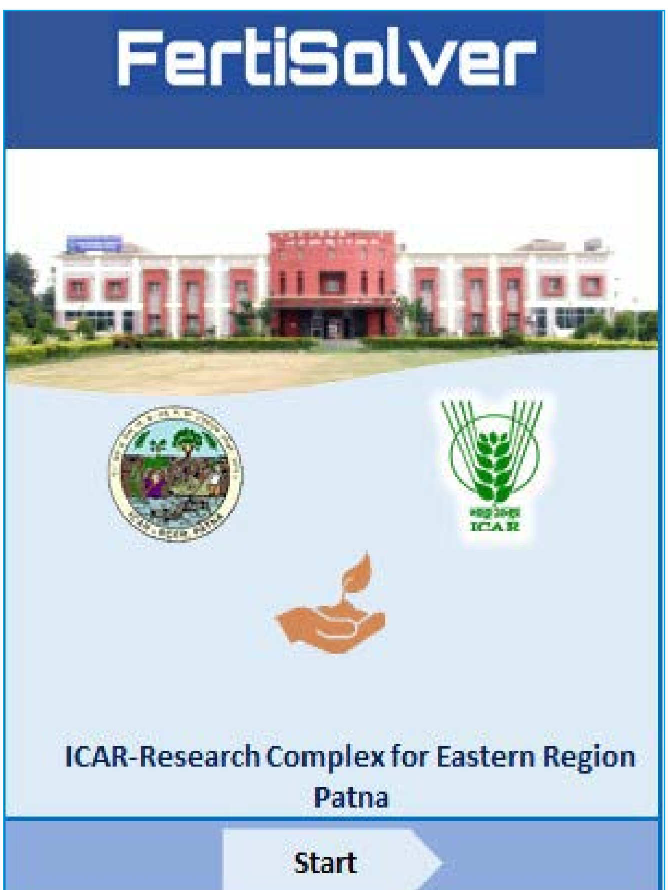


Fig. 13.10. The opening screen of FertiSolver

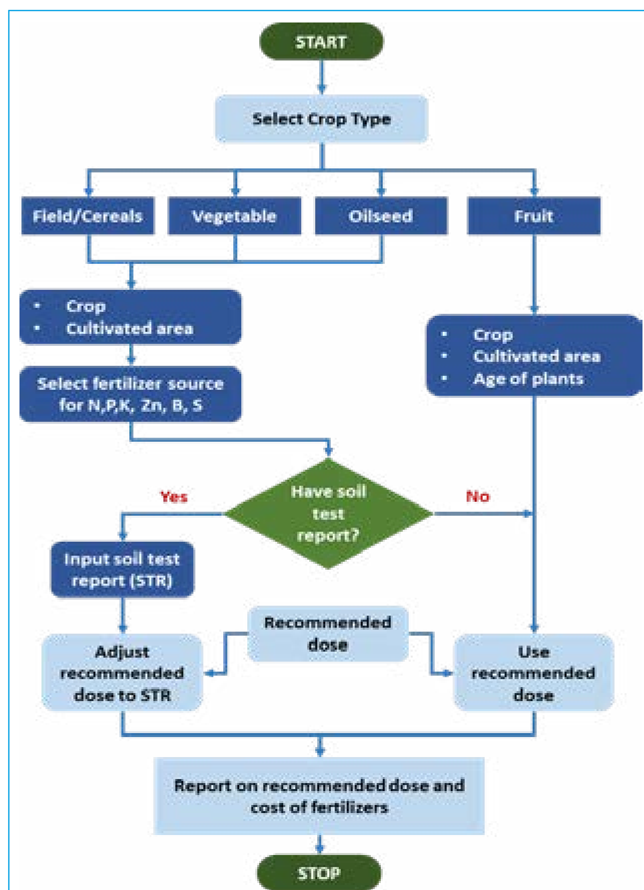


Fig. 13.11. The model architecture

FertiSolver is a completely offline soil test-based fertilizer recommender tool for desktop computers. The tool provides calculations according to the area of farm and type of crop using the principle of site-specific nutrient management. The FertiSolver has the capability to workout fertilizer requirements by comparing the recommended dose of fertilizers and the soil test reports. It has inbuilt database on recommended dose of fertilizers for major crops of Eastern Plateau and Hill Region (EPHR) of India.

FertiSolver is a decision support software for PCs with windows and MAC platforms enabling farmers and local experts to quickly work out the fertilizer recommendations for the major crops of EPHR. The tool will help farmers in increasing their yields and net returns by providing an optimal fertilizer management strategy based on soil test reports. Extent of area, type of crop and soil testing report (if available) are the main inputs to the tool. The user also gets a wide range of fertilizers to select from the drop down menus. The FertiSolver generates a detailed report on quantity of selected fertilizer required for the selected crop and area combination. The tool also presents a cost incurred on the choice of fertilizers. In addition, the FertiSolver is designed in such a way that users can go back and change the choice of fertilizers and assess the impact of changed fertilizers sources on total cost of fertilizers. So, this software acts as a learning tool—providing different combinations of fertilizers, instant summary tables and cost of fertilization – allowing a great amount of flexibility in navigating through the modules.

Study on Growth Stage Based Fertigation Patterns and Crop Geometry in Cucurbitaceous Crops in Eastern Hill Plateau Region Condition

The experiment was conducted to evaluate the efficacy of different growth stage based fertigation and crop geometry on yield potential of cucurbitaceous crops viz., Bottle gourd, Bitter gourd & Cucumber in acid soil of eastern hill & plateau region for commercial production of cucurbitaceous vegetables under drip irrigation system. The experiment comprised of three growth stage based fertigation level viz. F_1, F2 &F_3 and four crop geometry viz. S_1, S_2, S_3 & S_4 applied in twelve treatment combinations.

In Bitter gourd, crop geometry S2 (120 x 90 cm, square with one row per lateral accommodating 9259 plants / ha gave the highest mean yield (54.9 q/ha) (Fig13.12). Among fertigation Pattern, FP1 (constant fertilizer dose throughout the cropping season) gave highest mean yield (69.0 q/ha), whereas, among interaction, the FP1S2 gave highest yield (79.6 q/ha). In cucumber, planting geometry S2 gave highest mean yield (96.6 q/ha) (**Fig. 13.13**). In fertigation pattern, FP1 gave the highest mean yield (124.30 q/ha), whereas, interaction FP1S2 gave highest yield (133.40 q/ha).

Cucumber grown during the summer season, the crop geometry S2 gave highest mean yield (197.9 q/ha),WP (17.8 kg/m3) and EWP (Rs 158.4/m3) (Fig. 13.14). The fertigation pattern FP1 gave highest mean yield (233.8 q/ha), WP (17.8 kg/m^3) & EWP (Rs 187.1 m^3). Interaction between FP1& S2 gave highest yield (279.5 q/ha), WP (21.3 kg/m^3) & EWP (Rs 223.6 m^3).

Bitter gourd grown in summer season, S1-80 x 80 cm square with one row per lateral of 15625 plant /ha) gave highest mean yield (100.8 q/ha),WP (12.2 kg/m^3) and EWP (Rs 211.8/m^3) (**Fig. 13.15**). The FP1 (constant fertilizer dose throughout the cropping season) gave highest mean yield (112.9 q/ha),WP (13.6 kg/m^3) & EWP (Rs 237.0 m^3). The interaction effect of FP1& S2 resulted in highest yield (125.2 q/ha), WP (15.1 kg/m^3) & EWP (Rs 262.9 m^3).

Bottle gourd grown during summer season, S2 gave highest mean yield (55.1 q/ha), WP (4.6 kg/m^3) and EWP (Rs 46.3/m^3) (Fig. 13.16). FP1 gave highest mean

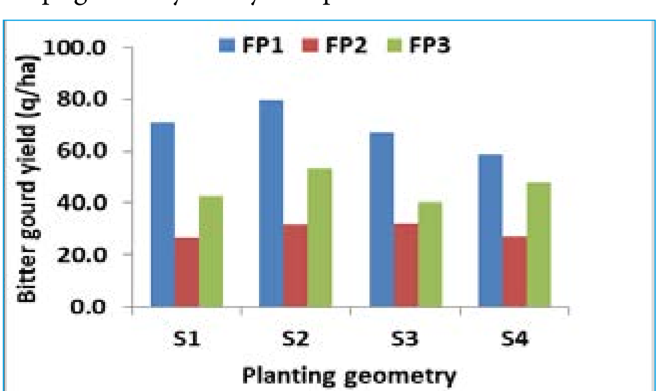


Fig. 13.12. Effect of planting geometry and fertigation pattern on yield of bitter gourd

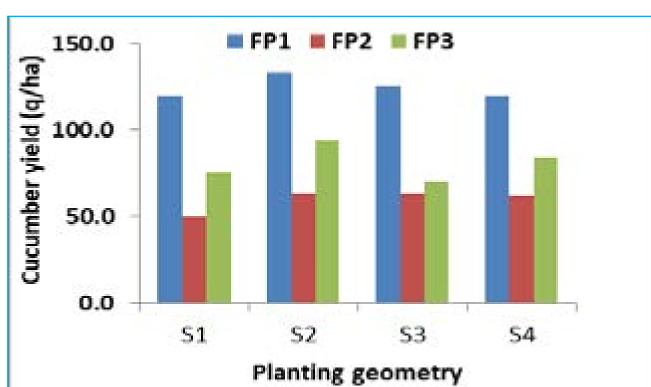


Fig.13.13. Effect of planting geometry and fertigation pattern on yield of cucumber

yield (71.8 q/ha),WP (6.0 kg/m^3)& EWP (Rs60.3 m^3). Interaction between FP1 & S1 gave highest yield (76.9q/ha), WP (6.5 kg/m^3) & EWP (Rs 64.6 m^3).

Hence, closely spaced square planting geometry with row to row and plant to plant spacing of 80 x 80 cm (15625 plants per ha) application of uniform fertilizer dose (80:40:40 kg NPK) in 16 to 18 splits is recommended for commercial cultivation of cucurbitaceous crops in EPHR.

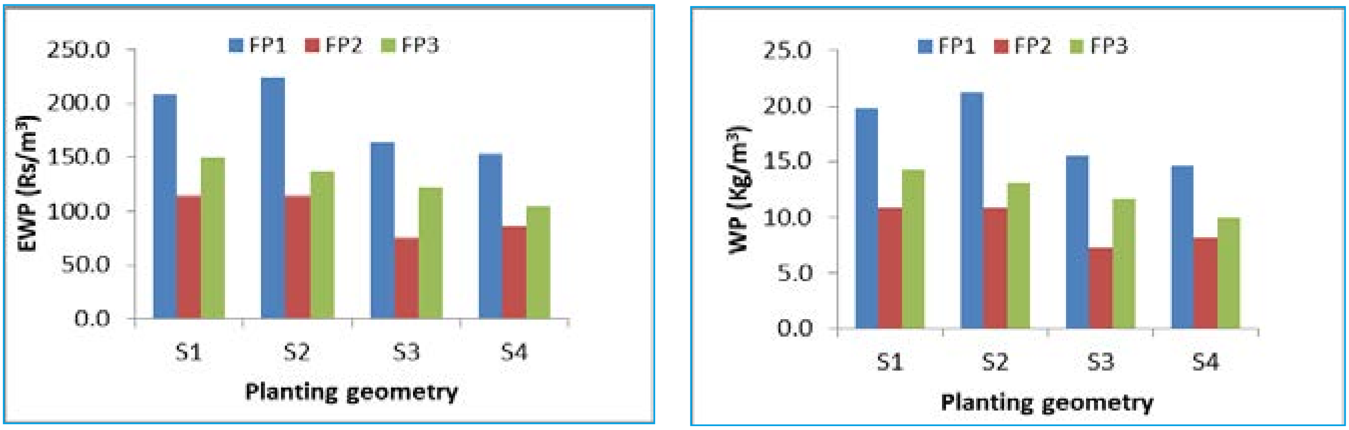


Fig. 13.14. Effect of planting geometry and fertigation pattern on yield, economic water productivity and water productivity of summer season grown cucumber

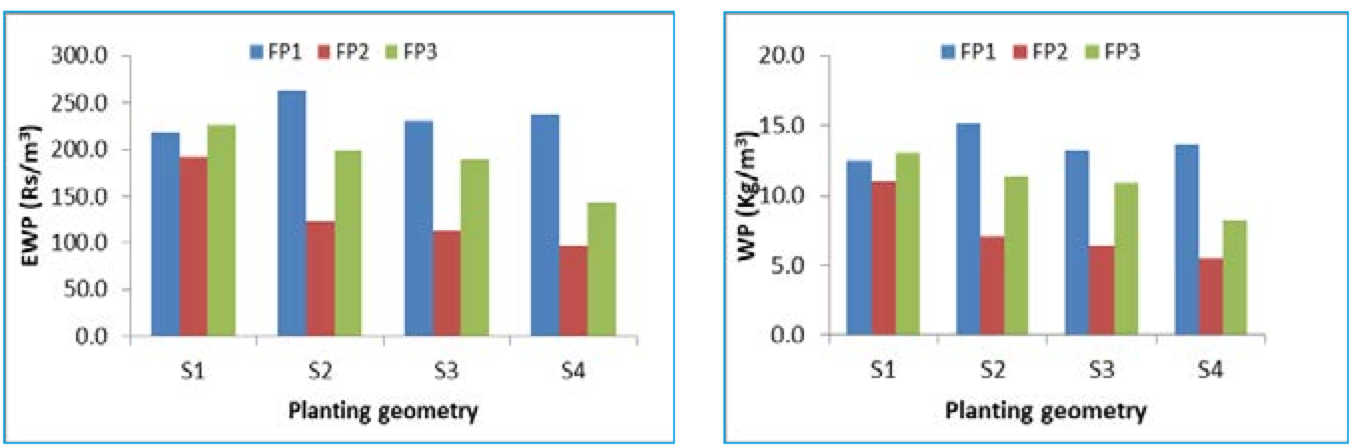


Fig. 13.15. Effect of planting geometry and fertigation pattern on economic water productivity and water productivity of summer season grown bitter gourd

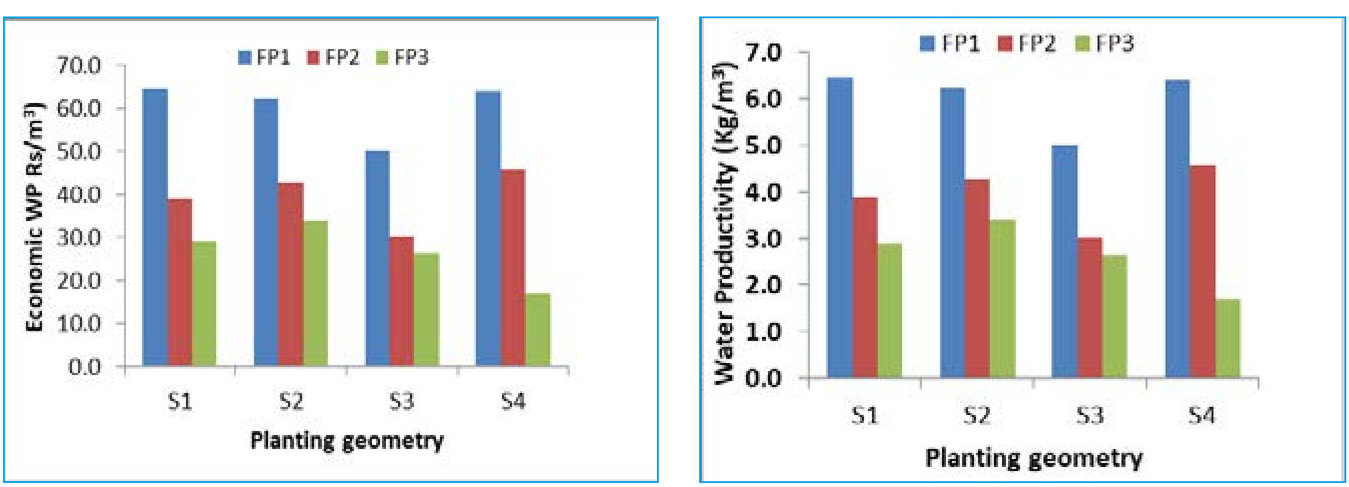


Fig. 13.16. Effect of planting geometry and fertigation pattern on yield, economic water productivity and water productivity of summer season grown bottle gourd

14. Water Quality and Productivity

Optimization of Cropping Pattern to Maximize Water Productivity

For efficient utilization of water in cereals and horticultural crops, an optimum allocation of land area under different components is of vital importance. To further refine the study, a survey was conducted in the command of Paliganj distributary and Nalanda corridor (groundwater irrigated) and data about inputs applied (like seeds, fertilizer, insecticides/ pesticides, land preparation, farm implements, water and labour) and cereal, pulses as well as horticultural outputs produced along with cost were collected through developed questionnaire from representative farmers. Water productivity maximization problem was formulated, and prevailing constraints were decided after due interaction with farmers for both project sites. The objective function was common, but constraints were different. The objective function, maximization of water productivity (Z_{WP}) was defined as

$$MaxZ_{WP} = [\sum_{i=1}^{N}\sum_{j=1}^{M}\frac{1}{IA_{ij}}[A_{ij}(Y_{ij}P_{ij} + YB_{ij}PB_{ij} - CP_{ij}) - \sum_{i=1}^{N} PCW_i \times A_i - PGW \times NH]]$$

where

Z_{WP} is net annual return from all the crops per unit of applied irrigation water (Rs.-ha/m^3); i = index for crop season (i = 1 for monsoon or *kharif* season, 2 for non-monsoon or *rabi* season, 3 for summer season and 4 for horticultural crops); j is the index for crop name; A_{ij} was the area (ha) to be allocated in ith season for jth crop ; IA_{ij} was the irrigation applied in ith season for jth crop (m^3); Y_{ij} is the yield of jth crop grown in ith season (kg/ha); P_{ij} was the current market price of jth crop ith season (Rs./kg); YB_{ij} was the yield of by-product of jth crop grown in ith season (kg/ha); PB_{ij} was the prevailing market price of by-product of jth crop in ith season (Rs./kg); CP_{ij} was the cost of production (excluding irrigation water price) of the jth crop grown in ith season (Rs./ha); PCW_i = price for canal water paid (Rs./ha); A_i is area covered by crops during monsoon, non-monsoon, summer season and horticultural crops; PGW was the price paid for ground water applied (Rs./hr); NH was the number of hours of operation in providing irrigation. The constraints for the Paliganj site were

1. $A_R + A_{MK} \leq 3410$ ha
2. $A_W + A_L + A_{KH} + A_G + A_{MR} + A_P \leq 3410$ ha
3. $A_O + A_{GG} \leq 1705$ ha
4. $A_R \geq 1705$ ha
5. $A_W \geq 1023$ ha
6. $A_{MA} + A_{GU} \leq 10$ ha

Canal and Ground water availability constraints

7. $0.66\ A_R + 0.225\ A_{MK} \leq 1498.94$ ha-m
8. $0.015\ A_R + 0.225A_W + 0.125A_L + 0.125A_{KH} + 0.125A_G + 0.375A_{MR} + 0.225\ A_P + 0.445A_o$ $+ 0.152\ A_{GG} + 0.005\ A_{MA} + 0.0025A_{GU} \leq 323.64$ ha-m

Man-days requirement constraints

9. $120\ A_R + 40\ A_{MK} + 100\ A_W + 40\ A_L + 40\ A_{KH} + 45\ A_G + 40A_{MR} + 56A_P + 110A_O + 40\ A_{GG} + 300A_{MA} + 275A_{GU} \leq$ 500000 man-days

Here A_R, A_{MK}, A_W, A_L, A_{KH}, A_G, A_{MR}, A_P, A_O A_{GG} A_{MA} and A_{GU} were the areas allocated under rice, kharif maize, wheat, lentil, khesari, gram, maize rabi, potato, onion, green gram (agricultural crops) and mango and guava (horticultural crops), respectively. The value of water productivity considering the existing area under different crops and optimum water productivity after revising the allocation of the area under different crops employing the simplex linear programming technique is reported in (Table 14.1). It is concluded from above that the water productivity could be enhanced from existing 27.897 Rs./m^3 from 6703 ha area to 32.42 Rs./m^3 from 4700.13 ha area only; if areas under different crops are reallocated under cereal, pulses and horticultural crops and constraints of groundwater availability and other prevailing constraints in the project area are considered.

For the Nalanda corridor, the following constraints were formulated

Crop area constraints

1. $A_R \leq 400$ ha
2. $A_W \geq 200$ ha
3. $A_B \geq 6$ ha
4. $A_{MP} \geq 6$ ha

5. $A_W + A_L + A_G + A_{PE} + A_{MU} + A_C + A_B \leq 400$ ha

6. $A_{MA} + A_{GG} + A_{MP} \leq 300$ ha

7. $A_{PY} + A_{GU} \leq 12$ ha

Groundwater availability constraints

8. $0.225\ A_R \leq 81$ ha-m

9. $0.175A_W + 0.075A_L + 0.075A_G + 0.135A_{PE} + 0.1A_{MU} + 0.5\ A_C + 0.5A_B + 0.02\ A_{PY} + 0.002\ A_{GU} \leq 54$ ha-m

10. $0.35A_{MA} + 0.15A_{GG} + 0.5A_{MP} + 0.00975A_{PY} + 0.001\ A_{GU} \leq 27$ ha-m

Man-days requirement constraints

11. $118\ A_R + 75A_W + 42\ A_L + 30A_G + 66A_{PE} + 40A_{MU} + 24A_C + 25A_B + 64A_{MA} + 60A_{GG} + 25A_{MP} + 300\ A_{PY} + 275\ A_{GU} \leq 500000$ man-days

Here A_R, A_W, A_L, A_G, A_{PE}, A_{MU}, A_C, A_B, A_{MA}, A_{GG}, A_{MP}, A_{PY} and A_{GU} were the areas allocated under rice, wheat, lentil, gram, pea, mustard, coriander, berseam, maize, green gram MP chari, papaya and guava, respectively.

The value of water productivity considering the existing area under different crops and optimum water productivity after revising the allocation of areas under different crops employing the simplex linear programming method at the Nalanda Corridor site is given below in (Table 14.2).

Table 14.1. Existing and optimum water productivity computed at the Paliganj site

Sl. No.	Crops	Existing Area (ha)	Optimum area allocated (ha)
1	Rice	3083	1705
2	Maize (*kharif*)	10	1660.62
3	Wheat	1100	1023
4	Lentil	1200	0
5	Khesari	700	0
6	Gram	300	0
7	Maize (*rabi*)	30	0
8	Potato	80	301.51
9	Onion	90	0
10	Green Gram	100	0
11	Mango	8	10
12	Guava	2	0
	Total area	6703	4700.13
	Water Productivity (Rs/m^3)	186993.06 /6703 = 27. 90	157080.34/4700.13 = 32.42

Table 14.2. Existing and optimum water productivity computed at the Nalanda corridor site

Sl. No.	Crop	Existing Area (ha)	Optimum area allocated (ha)
1	Rice	400	360
2	Wheat	280	200
3	Lentil	10	194
4	Gram	10	0
5	Pea	4	0
6	Mustard	80	0
7	Coriander	10	0
8	Berseem	6	6
9	Maize	60	0
10	Green Gram	80	159.22
11	MP Chari	6	6
12	Papaya	4	12
13	Guava	8	0
	Total area	958	937.22
	Water Productivity (Rs/m^3)	32602.07/958 = 34.03	39593.31/937.22 = 42.25

Studies on Irrigation water pricing and influencing factors

In order to assess irrigation water price of different crops in Paliganj distributary command (irrigated with canal and groundwater) and Nalanda corridor site (irrigated by groundwater only), required data were collected from thirty farmers through a developed questionnaire. Results of the study are given in (Table 14.3 and 14.4) for the Paliganj distributary site and (Table 14.5 and 14.6) for the Nalanda Corridor site.

From the (Table 14.4), it is observed that the irrigation water price, considering irrigation water applied through both canal and tube well, in the Paliganj distributary for rice, kharif maize, wheat, lentil, khesari, gram, rabi maize, potato, onion and green gram crops in Rs./m^3 were 3.73, 22.60, 11.67, 21.50, 27.42, 23.27, 14.75, 98.06, 84.92, and 27.17, respectively. Maximum irrigation water price of 98.06 Rs./m^3 was for potato and minimum of 3.73 Rs./m^3 for rice was observed. This clearly shows that consumption of water by rice is quite high as compared to potato but profit from potato is maximum as compared to all other crops. Results reported in (Table 14.6) revealed that, at the Nalanda Corridor project site, irrigation water price of rice, kharif maize, wheat, lentil, gram, pea, mustard, potato, rabi maize, and green gram crops in Rs./m^3 was 12.54, 24.61, 18.71, 44.15, 39.53, 37.85, 32.35, 96.93, 15.44, and 30.25, respectively. Maximum irrigation water price of 96.93 Rs./m^3 was for potato and minimum irrigation water price of 12.54 Rs./m^3 was for rice. At the Nalanda corridor site, groundwater was used for irrigation and less amount of water (when essentially required) was applied, so the assessed irrigation water price was relatively higher.

Evaluation of irrigation system and improvement strategies for higher water productivity in Sone canal command

Estimated crop water requirement and net irrigation requirement for paddy crop with average seasonal grown area of 1009 ha for five years (2015 to 2019). Averaged ET of paddy was 725.2 mm, averaged effective rainfall was

Table 14.3. Data of farmers from Paliganj distributary

Crop	Rice	Maize (*kharif*)	Wheat	Lentil	Khesari
Input cost (including seed, organic matter, fertilizer, Insecticide, pesticide etc. excluding water) (Rs.)	8673	6840	10053	7299	5000
Labour cost involved in ploughing/ rotavator/ tilling/harrowing/ sowing/dibbling/planting/ transplanting/weeding/harvesting/ threshing etc. (Rs)	36000	12000	30000	12000	12000
Fixed cost including rental value of land, depreciation cost of farm building and implements and interest on fixed cost (Rs.)	23266	20059	22553	25225	25225
Total cost of cultivation (Rs.)	67939	38899	62606	4452	42225
Yield (t)	4.8	4.8	4.5	1.4	1.7
Sale price (Rs./t)	19400	18700	19750	5100	45000
Total Output (Rs.)	93120	89760	88875	7140	76500
Output-Input (Rs.)	25181	50861	26269	2687	34275
Crop	**Gram**	**Maize (*rabi*)**	**Potato**	**Onion**	**Greengram**
Input cost (including seed, organic matter, fertilizer, Insecticide, pesticide etc. excluding water) (Rs.)	12368	6840	58044	16044	7760
Labour cost involved in ploughing/ rotavator/ tilling/harrowing/ sowing/dibbling/planting/ transplanting/weeding/harvesting/ threshing etc. (Rs)	13500	12000	16800	33000	12000
Fixed cost including rental value of land, depreciation cost of farm building and implements and interest on fixed cost (Rs.)	26650	30569	17031	18813	11688
Total cost of cultivation (Rs.)	52518	49409	91876	67857	31448
Yield (t)	1.6	5.6	25	22.5	1
Sale price (Rs./t)	51000	18700	12500	20000	72750
Total Output (Rs.)	81600	104720	312500	450000	72750
Output-Input (Rs.)	29082	55311	220624	382143	41303

Table 14. 4. Irrigation water price (Rs./m^3) computation based on irrigation water applied

Crop	Rice	Maize (*kharif*)	Wheat	Lentil	Khesari	Gram	Maize) (*rabi*)	Potato	Onion	Green gram
Source of water	**Volume of water applied (m^3)**									
Canal	6600	2250	1500	900	900	900	2000	1000	1000	0
Tubewell	150	0	750	350	350	350	1750	1250	3500	1520
Total irrigation applied	6750	2250	2250	1250	1250	1250	3750	2250	4500	1520
Profit (Rs.)	25181	50861	26269	26876	34275	29082	55311	220624	382143	41303
Irrigation water price (Rs/m3)	3.73	22.60	11.67	21.50	27.42	23.27	14.75	98.06	84.92	27.17

Table 14.5. Data of farmers from Nalanda corridor site

Crop	Rice	Maize (*kharif*)	Wheat	Lentil	Gram
Input cost (including seed, organic matter, fertilizer, Insecticide, pesticide etc. excluding water) (Rs.)	7720	6840	12520	9010	14410
Labour cost involved in ploughing/ rotavator/ tilling/harrowing/sowing/ dibbling/planting/transplanting/weeding/harvesting/threshing etc. (Rs)	35400	12000	22500	12600	9000
Fixed cost including rental value of land, depreciation cost of farm building and implements and interest on fixed cost (Rs.)	21781	19288	21116	21781	23444
Total cost of cultivation (Rs.)	64901	38128	56136	43391	46854
Yield (t)	4.8	5.0	4.5	1.5	1.5
Sale price (Rs./t)	19400	18700	19750	51000	51000
Total Output (Rs.)	93120	93500	88875	76500	76500
Output-Input (Rs.)	28219	55373	32739	33109	29646
Crop	**Pea**	**Mustard**	**Potato**	**Maize (*Rabi*)**	**Green gram**
Input cost (including seed, organic matter, fertilizer, Insecticide, pesticide etc. excluding water) (Rs.)	6490	4120	58044	12680	7760
Labour cost involved in ploughing/ rotavator/ tilling/harrowing/sowing/ dibbling/planting/ transplanting/weeding/harvesting/threshing etc. (Rs)	19800	12000	16800	19200	18000
Fixed cost including rental value of land, depreciation cost of farm building and implements and interest on fixed cost (Rs.)	22613	21283	20238	24275	23444
Total cost of cultivation (Rs.)	48903	37403	95082	56155	49204
Yield (t)	5.0	1.5	25.0	6.1	1.3
Sale price (Rs./t)	20000	46500	12500	18700	72750
Total Output (Rs.)	100000	69750	312500	114070	94575
Output-Input (Rs.)	51098	32348	217418	57915	45371

Table 14.6. Irrigation water price (Rs./m^3) computation based on water applied

Crop	Rice	Maize (*khari*)	Wheatt	Lentil	Gram	Pea	Mustard	Potato	Maize (*rabi*)	Green gram
Source of water	**Volume of water applied (m^3)**									
Canal	0	0	0	0	0	0	0	0	0	0
Tubewell	2250	2250	1750	750	750	1350	1000	2250	3750	1500
Total irrigation applied	2250	2250	1750	750	750	1350	1000	2250	3750	1500
Profit (Rs.)	28219	55373	32739	33109	29646	51098	32348	217418	57915	45371
Irrigation water price (Rs/ m3)	12.54	24.61	18.71	44.15	39.53	37.85	32.35	96.93	15.44	30.25

468.9 mm and averaged net irrigation water was 656.3 (including average 200 mm of water used in puddling). (Fig. 14.1) shows the gap between average demand and supply of irrigation water in Paliganj distributary with CCA, approximately, 6000 ha.

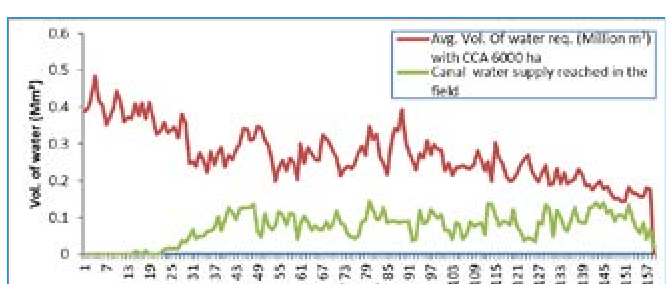


Fig 14.1. Canal water supply vs demand during *kharif* (2015-19)

Flood hazard mapping for Bihar

The extent of flood was mapped and zoning of flood-prone areas was carried out as per flood hazard risks using Remote Sensing and Geographical Information

(RS & GIS) techniques. The zoning of the flood-prone areas helps in identifying and implementing suitable techniques for enhancing land and water productivity. Results showed that about 26073.0 km^2 area, i.e., 27.6% of total geographical area of Bihar is flood-prone and about 75.0% of the flood-prone area is in the North Bihar (Fig. 14.2). Some of the mostly flooded districts are Darbhanga, Madhubani, East Champaran, Muzaffarpur, and Samastipur. Zoning of the flood hazard areas as per their vulnerability to the flood revealed that about 525.1 km^2 area of the state comes under very high risk, 804.1 km^2 under high risk, 2461.6 km^2 under moderate risk, 5738.2 km^2 under low risk and 16544.0 km^2 under very low risk zone (Fig. 14.3). It was also observed that most of the areas have very high and moderate risk flood hazards and are located in Darbhanga, Muzaffarpur, Samastipur, East Champaran, and Khagaria districts. Field survey in the flood-affected regions of the state revealed that the depth of floodwater in these districts varies from 0.5 to 2.5 m and duration of flood ranges from 20 to 90 days.

Assessment of linseed water productivity

In this activity, four sets of water management practices were undertaken to determine linseed water productivity. These were (1) rainfed, (2) one irrigation at 70 DAS; (3) two irrigations i.e. first irrigation 45-50 DAS & second irrigation 85-90 DAS; (4) Three irrigations i.e., first at 30-35 DAS, second irrigation at 65-70 DAS, and third at 85-90 DAS. 40 mm water was supplied in each irrigation (Fig. 14.4). Crop received 62 mm of rainfall during the whole crop cycle.

Perusal of data presented in (Table 14.7) revealed that the highest plant height of 91.2 cm was recorded in the plots, where 3 irrigations were applied; however lowest of 52.9 cm plant height was recorded in case of rainfed plots. A similar trend was observed in case of biological yield (kg/ha), seed yield (kg/ha), straw yield (kg/ha) and Harvest Index. Highest seed yield (1477 kg/ha), biological yield (4610 kg/ha) were recorded when linseed crop received three irrigations. Numerically, highest harvest Index (0.34) was obtained in the plot, which received one irrigation. Highest water productivity (1.28 kg/m^3) was recorded in rainfed crop, however lowest (0.81 kg/m^3) was obtained in the plots, where three irrigations were applied.

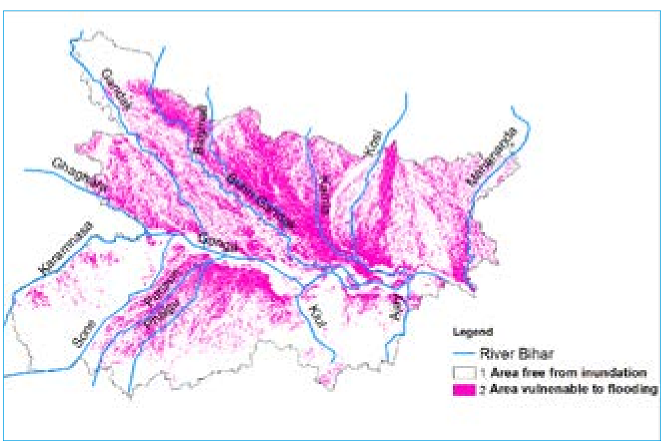


Fig. 14.2. Flood prone areas in Bihar

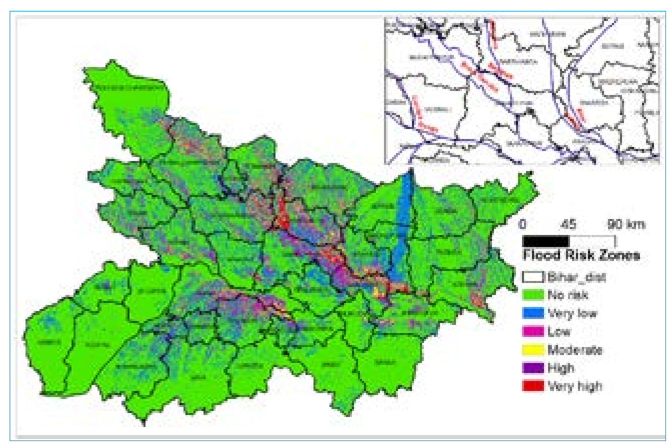


Fig. 14.3. Flood hazard zones of Bihar

Table 14.7. Linseed water productivity

Treatment	Plant height (cm)	Biological yield (kg/ha)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest Index	Water productivity (Kg/m^3)
Rainfed	52.9	2506	793	1713	0.32	1.28
One irrigation	78.8	3732	1255	2477	0.34	1.23
Two irrigations	83.4	4112	1341	2771	0.33	0.94
Three irrigations	91.2	4610	1477	3133	0.32	0.81
CD (5%)	9.23	187.2	123.7	146.3	NS	0.11

Fig. 14.4. Linseed crop under different water productivity treatment

Assessment of Land Use and Land Cover Changes for Crop Planning Using Remote Sensing and GIS in East and West Champaran Districts of Bihar

LANDSAT TM and LISS III images for the years 2000, 2011 and 2018 were collected from different websites. Collected images were in different parts as per availability. After collection, these images were mosaicked and arranged according to the district boundaries of East and West Champaran. Images were georeferenced. Classification and map generation of East and West Champaran were done for different land use and land covers (LULC) using ERDAS IMAGINE 4.1 and ArcGIS 10.3 with change detection in LULC. The main land use and land covers were agricultural/ crop land, fallow land, built-up area (urban/ dense built-up and rural/ low built-up), wet land (rivers/ ponds/ lakes), barren land (by the side of rivers) and vegetation/ forest. After classification of images, producer, user accuracies and kappa coefficients were calculated from confusion matrices. Land use/ land cover area of East Champaran and West Champaran in the year 2000, 2011 and 2018, and total as well as percentage change of LULC in 18 years are reported in (Table 14.8 and Table 14.9), respectively.

Evaluation of water budgeting parameters in Paddy

A field experiment was conducted to determine water balance components in paddy crop (Swarna Shreya) using drum culture technique during *kharif* season, 2020-21 (Fig. 14.6). In this experiment similar

Table 14.8. Land use/ land cover area of East Champaran in the year 2000, 2011 and 2018 and total and percentage change of LULC in 18 years

LULC (Area in km^2)	2000	2011	2018	Total change	% change
Crop land (Agriculture)	2182.45	2754.82 (+620.37)	3092.52 (+337.70)	+ 958.07	+43.9
Fallow land	1258.86	672.34 (-556.52)	305.36 (-366.98)	-923.50	-73.36
Dense builtup (urban)	18.24	25.36 (+7.12)	27.45 (+2.09)	+9.21	+50.5
Low buildup (rural)	112.35	282.28 (+169.35)	332.32 (+50.04)	+219.39	+195.27
River wet land	256.32	128.16 (-130.16)	118.38 (-9.78)	-139.94	-54.6
Lakes-ponds- wetland	28.96	18.32 (-10.64)	17.62 (-0.7)	-10.71	-37.00
Barren land	110.76	86.58 (-24.18)	74.28 (-12.30)	-36.48	-32.94
Total	3967.94 (3968)	3967.86 (3968)	3967.93 (3968)		

Table 14.9. Land use/ land cover area of West Champaran in the year 2000, 2011 and 2018 and total and percentage change of LULC in 18 years

LULC (Area in km²)	2000	2011	2018	Total change	% change
Crop land (Agriculture)	2306.42	2986.38 (+679.96)	3552.50 (+566.12)	+1246.08	+54.02
Fallow land	1428.32	757.14 (-671.18)	216.58 (-540.56)	-1211.74	-84.83
Dense buildup (urban)	12.98	20.12 (+7.14)	25.06 (+4.94)	+12.08	+93.07
Low buildup (rural)	89.12	229.06 (+139.12)	269.82 (+40.76)	+179.88	+201.84
River wet land	392.34	312.58 (-79.76)	268.46 (-44.12)	-123.88	-31.57
Lakes-ponds- wetland	5.16	3.08 (-2.08)	2.74 (-0.34)	-2.42	-46.90
Barren land	238.56	186.84 (-51.72)	162.68 (-24.16)	-75.88	-31.80
Forest	755.23	732.98 (-22.25)	731.36 (-1.62)	-23.87	-3.16
Total	5228.13 (5228)	5228.18 (5228)	5228.20 (5228)		

situation was maintained in field and drum and water balance components were accounted in water budgeting under regular monitoring of water loss from each drum on daily basis. Results are summarized in (Table 14.10). The percolation beyond root zone of the crop and water losses through evapotranspiration were 262.48 mm and 369.4 mm, respectively under conventional method which was about 35.36% & 49.77% of total water applied during 2021 and rest amount of water (14.87%) was stored within crop root zone (Fig. 14.7). Crop coefficient values of transplanted rice were also estimated at different crop growth stages at regional scale and results showed that these values differ considerably as suggested by FAO for transplanted rice (Fig. 14.8). Moreover, the grain yield was 0.548 kg/m^2 and irrigation water productivity was estimated to be 0.74 kg/m^3. This study would help in water resources management in rice transplanted areas of Indo-Gangetic plains (IGP) of India.

Prioritization of Watersheds for Soil and Water Conservation Measures in Nalanda, Bihar

Rainfall variation of Nalanda was studied using Modified Mann-Kendall (MMK) test with Theil-Sen estimator and Trend analysis of rainfall variation in pre-monsoon, monsoon and post monsoon season is shown in Fig 14.9 (a, b and c). Results revealed that there was a declining trend of rainfall in monsoon (1.7 mm/ year) and post monsoon (0.6 mm/ year) but significant increasing trend in pre-monsoon (1.5 mm/year) during the last 35 years (1985-2020). Hydrological study using morphometric characteristics and their prioritization at watershed scale by remote sensing and GIS - in addition to weighted sum approach technique was carried out in Nalanda, Bihar. The morphometric analysis shows that most of the watersheds are of 5th order, elongated in

Fig. 14.6. Experimental field with paddy

Table 14.10. Water balance components of paddy

Crop	Rainfall	Irrigation	ETc	DP	Runoff	±ΔS
	In mm					
Paddy Swarna Shreya	492.2	250	369.4 (49.77%)	262.48 (35.36%)	0	110.32 (14.87%)

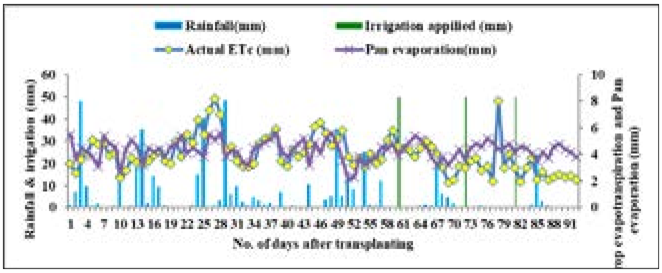


Fig. 14.7. Variation of water balance components of paddy

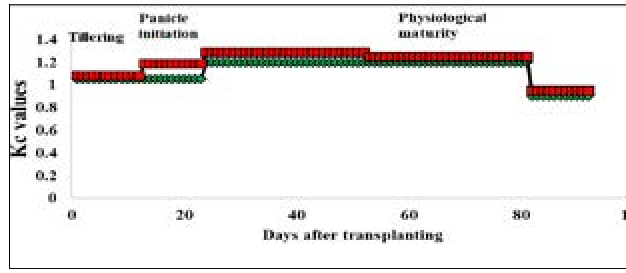


Fig. 14.8. Crop coefficient values at different crop growth stages

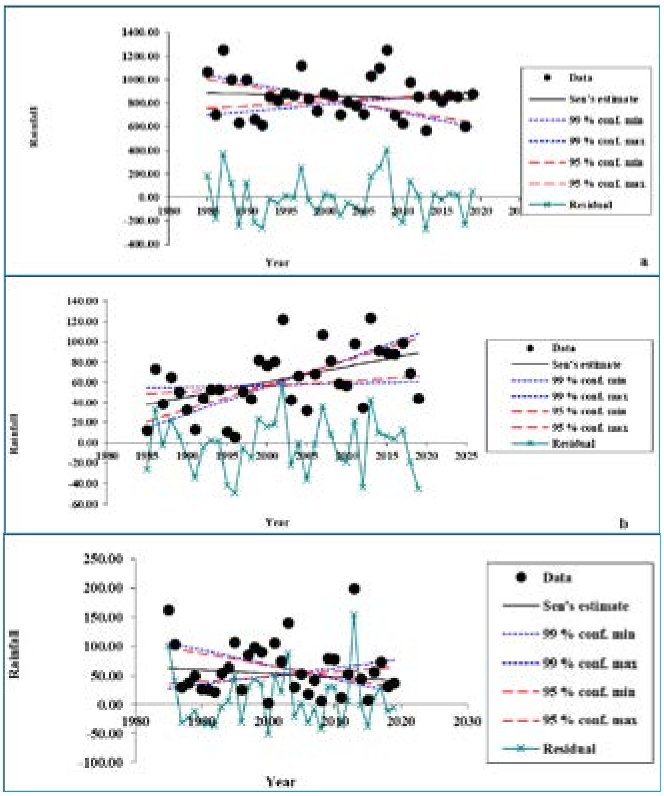


Fig. 14.9. Rainfall variation during a) Monsoon season, b) Pre-monsoon season, and c) Post-monsoon season

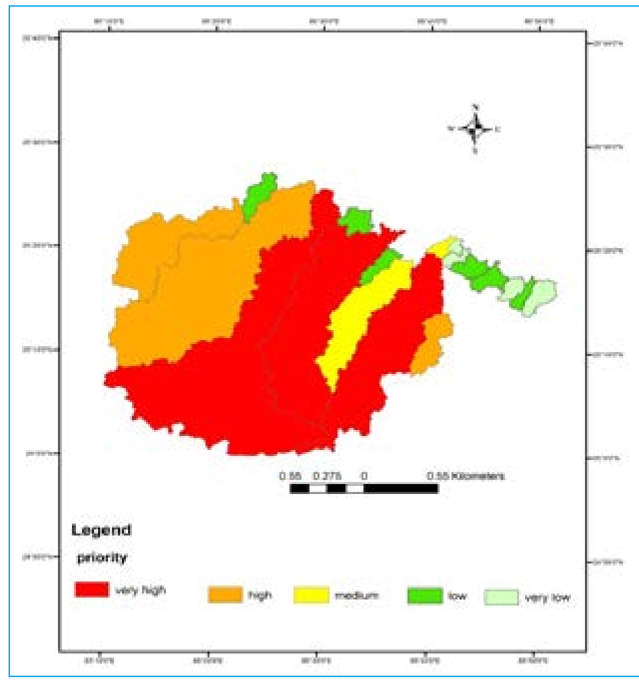


Fig. 14.10. Priority map showing prioritization of watersheds

shape followed by dendritic to sub dendritic drainage pattern. However, overall analysis illustrates that about 56.3% watershed areas (like Laranpur, Giriak, Rajgir, Silao etc.) come under high priority. However, (30.5%) come under moderate and only 2-4% watershed areas come under low to very low priority for implementation of soil and water conservation measures (Fig. 14.10). Study shows that, the water harvesting structures like farm pond, check dam, tanks, ahar-pyne, contour bunding and conservation ditches can be viable options for harvesting of surface runoff in high prioritized areas.

Impact of agricultural intensification on water table fluctuations in Eastern Gangetic Plains of India

Ground water dependent agricultural intensification has led to unsustainability of ground water systems in many parts of the world. The unconfined aquifers in Eastern Indo-Gangetic Plains (EIGP) of India are one of the most extensive aquifer systems in South Asia and are prone to ever intensifying agricultural systems. Long term impacts of agricultural intensification on ground water dynamics in an agriculturally important sub-region of EGP was evaluated using a multi-model approach, combining the capabilities of vadose zone model (HYDRUS-1D) and aquifer simulation model (MODFLOW). The general modelling protocol is presented in (Fig. 14.11). The study, mathematically reconstructed the vadose zone and aquifer geometry and implemented them into flow models. Loosely coupled vadose zone and ground water flow modelling framework is highly suitable for simulating the impact of changed cropping intensity on ground water dynamics. The recharge estimates from HYDRUS-1D and calibration of regional ground water flow model offered a robust set of parameter values for prevalent conditions of EIGP.

The results showed good correspondence between the observed and simulated water table levels during calibration, with RMSE=0.56-0.59 m, NSE=0.76-0.99 and R^2= 0.83-0.91, all within acceptable limits. Spatial distribution of water table under different intensification scenarios is shown in Fig. 14.12 (a-d). Projections showed that although the water table in the region would remain fairly stable under lower levels of cropping intensity (135-150%), further increase to 200 and 300% would lead to water table decline at the rate of 0.87 and 1.83 meter per year, respectively. These changes could therefore impact future ground water risk management in EIGP. This reinforces the view that, ground water dependent intensification may be sustainable in long term only if adaptation strategies and compensatory measures are adopted.

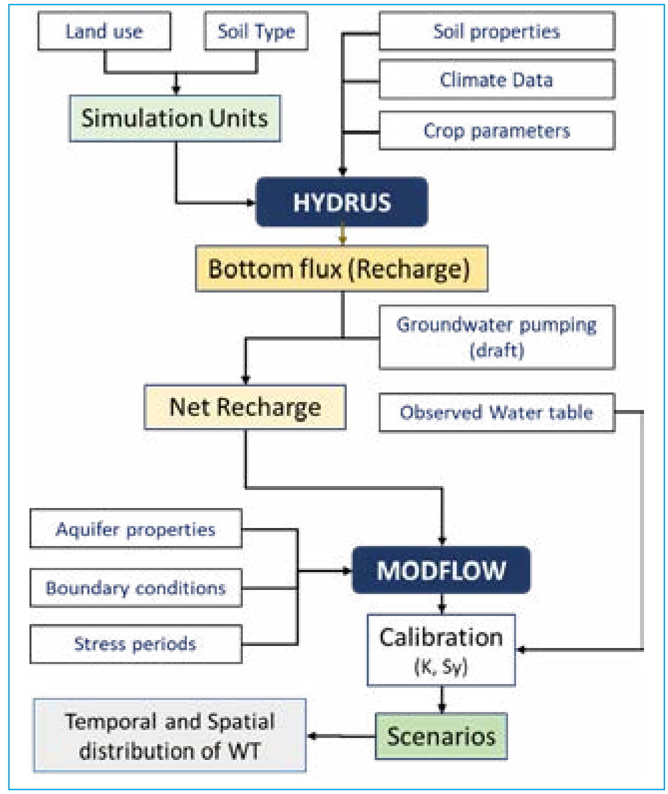


Fig. 14.11. Flow chart of the modelling procedure for recharge estimation and simulation of water table fluctuation (K=horizontal hydraulic conductivity, Sy=Specific yield)

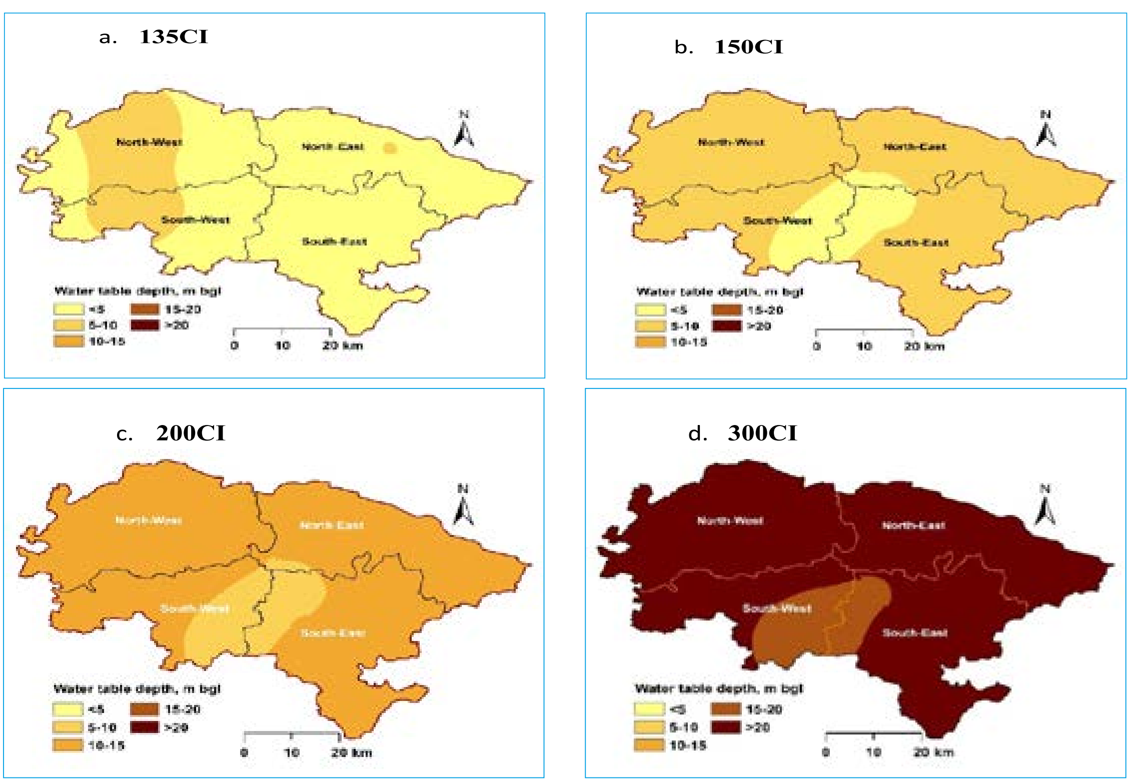


Fig. 14.12 (a-d). Spatial distribution of water table levels (m below ground level) at the end of simulation period of 10 years under different cropping intensity scenarios. a. prevailing cropping intensity (135%) b. 150% cropping intensity c. 200% cropping intensity d. 300% cropping intensity.

15. Conservation Agriculture

Effects of Long-Term Conservation Agriculture (CA) on Productivity of Rice-based Cropping System

A long-term field experimentation was undertaken under CSISA (Cereal Systems Initiative for South Asia) project phase III on CA in rice-based cropping systems at ICAR RCER Patna since 2009-10. After the 7th year, ZTDSR under CA-based rice-mustard-maize system faced a severe problem of rice mealy bug (*Brevennia rehi*), and hence, crop field was divided into 4-plots (ZTDSR, CTDSR, puddle transplanted and unpuddle transplanted). After two years of the tillage, these plots were again converted into ZTDSR production system. The results after 11th year revealed that the maximum rice yield (6.09 t/ha) was recorded with CTR, however, it was at par with MTR and CTDSR system (Table 15.1 and Fig. 15.1).

Fig. 15.1. Performance of rice in diverse tillage-cum-crop establishment methods

In the same project an experiment was initiated in 2015 to study the long-term effect of crop establishment methods in rice-wheat-mungbean system. Result of 7th years study revealed that ZTDSR production system yielded the maximum rice grain (6.97 t/ha) which was at par with PLTR (6.87 t/ha) production system (Table 15.2 and Fig. 15.2).

RPTR: Random puddle transplanted rice, CTW: Conventional-till wheat, CTM: Conventional-till mungbean, PLTR: Puddle line transplanted rice, CTMTR: Conventional-till machine transplanted rice,

Table 15.1. Rice yield as influenced by different tillage-cum-crop-establishment methods following long-term conservation agriculture practices

Crop scenario	Crop establishment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)
CTR-CTW-Fallow	Broadcasted	6.09^{A}	5.04^{B}	11.13^{A}
MTR-ZTW-ZTMU	MTR	6.03^{A}	5.84^{A}	11.87^{A}
ZTDSR-ZTW-ZTM	ZT	5.60^{A}	4.60^{B}	10.20^{B}
ZTDSR-ZTM-ZTM	ZT	5.87^{A}	3.43^{C}	9.30^{C}

CTR: Conventional-till rice, MTR: Machine transplanted rice, CTW: Conventional-till wheat, ZTMU: Zero-till mungbean, ZTDSR: Zero-till direct seeded rice, ZTM: Zero-till mustard

Table 15.2. Rice yields as influenced by different tillage-cum-crop establishment methods following long-term conservation agriculture practices

Tillage-cum-crop establishment methods	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)
RPTR-CTW-CTM	6.14^{B}	7.62^{A}	13.8^{AB}
PLTR-CTW-CTM	6.87^{A}	5.37^{C}	12.2^{C}
CTMTR-ZTW-ZTM	6.17^{B}	5.57^{C}	11.7^{CD}
ZTMTR-ZTW-ZTM	5.84^{B}	5.38^{C}	11.2^{C}
SRI-SWI-ZTM	6.50^{B}	6.93^{B}	13.4^{AB}
CTDSR-ZTW-ZTM	5.86^{B}	7.28^{B}	13.1^{B}
ZTDSR-ZTW-ZTM	6.97^{A}	7.12^{B}	14.1^{A}

Fig. 15.2. Performance of rice in diverse tillage-cum-crop establishment methods

ZTMTR: Zero-till machine transplanted rice, SRI: System of rice intensification, SWI: System of wheat intensification, CTDSR: Conventional-till direct seeded rice, ZTDSR: Zero-till direct seeded rice

Water Conservation under Different Irrigation and Tillage Management in Rice-based Cropping Systems

Puddled transplanted rice (PTR) resulted in a yield of 4.12 t/ha which was significantly higher than unpuddled transplanted rice (UPTR) (3.58 t/ha). However, the yield of wheat among different irrigation management and tillage methods was similar (Table 15.3) and ranged between 3.96-4.46 t/ha (for irrigation methods) and 4.12-4.42 t/ha (tillage methods). In contrast, maize yield varied significantly among different tillage and residue management practices. Soil moisture based irrigation yielded highest maize yield which was similar to farmers' practice but significantly higher (5%; $p<0.05$) than the deficit irrigation method. Similarly, zero-tillage method resulted in higher yield (15%; $p<0.05$) than conventional tillage practices.

After three years of adoption, notable changes in soil organic C (SOC) and available N were observed (Fig. 15.3). Changes were more prominent up to a soil depth of 15 cm and thereafter, the magnitude of impact reduced considerably. The adoption of ZT caused a significant gain in SOC and available N content particularly in the 0-7.5 cm soil layer. Among the cropping system, rice-wheat cropping system showed much improvement in soil fertility in terms of SOC and available N than rice-maize cropping system. Maize is an exhaustive crop and takes up more nutrients from soil and therefore, reduced the soil fertility level than rice-wheat system.

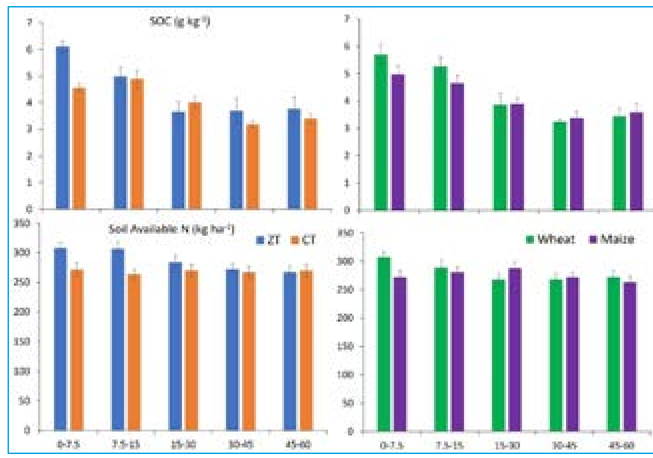


Fig. 15.3. Soil organic C and available nitrogen as affected by different tillage and cropping systems

Standardization of Basin Enrichment in Bearing Orchards of Bael, Mango and Guava Under Eastern Plateau and Hill Region

Under the experiment is being conducted since 2020 to study the effect of mulching with Tephrosia biomass on plant growth, yield and fruit quality of bael, mango

Table 15.3. Yield of wheat and maize as affected by different tillage and irrigation management practices.

Tillage	Irrigation methods			Tillage mean	p-value
	Farmers' practice	Soil moisture based irrigation	Deficit irrigation		
Wheat					
CT	4.22	4.31	3.84	4.12	Tillage = ns
ZT	4.56	4.61	4.08	4.42	Irrigation = ns
Irrigation Mean	4.39	4.46	3.96	GM = 4.27	Tillage x Irrigation = ns
Maize					
CT	6.56	6.51	6.33	6.47^{B}	Tillage = 0.049*
ZT	7.50	7.68	7.20	7.46^{A}	Irrigation = <0.01*
Irrigation mean	7.03^{A}	7.09^{A}	6.76^{B}	GM = 6.96	Tillage x Irrigation = 0.03*

and guava. The treatments comprised of application of mulching tree basin with Tephrosia biomass @ 1 kg dry wt/m², 1.5 kg dry wt/m² and 2.0 kg dry wt/m². Significant effects of the treatments were recorded on plant growth parameters, yield and soil properties in bael and mango. In bael (Table 15.4), all the treatments resulted in significant increase in the trunk diameter over that of control. However, mulching with 2 kg dry biomass of Tephrosia per m² basin area resulted in the maximum fruit yield per tree. In mango, all the treatments resulted in significantly higher values of trunk diameter and fruit yield per tree over that of control and were at par with each other.

Effect of biomass mulching on soil chemical properties in bael orchard is presented in Table 15.5. All the treatments on mulching resulted in significant increase in the content of soil organic carbon, available nitrogen and exchangeable potassium in 0-15 cm soil layer. Application of 1.5 kg dry biomass per m² resulted in the highest content of available phosphorus in 0-15 cm soil layer.

In case of mango, biomass mulching resulted in significant change in different soil chemical parameters particularly in the 0-15 cm soil layer (Table 15.6). All the treatments on mulching were at par with respect to the content of soil organic carbon, available nitrogen and exchangeable potassium in 0-15 cm layer and were significantly higher than control.

Hence, after one year of experimentation, all the treatments on mulching were found to be equally effective in improving the soil fertility, plant growth and yield of mango and guava.

Table 15.4. Effect of biomass mulching on plant growth parameters of bael and mango

Treatment	Bael		Mango	
	Trunk diameter (cm)	Yield (kg/plant)	Trunk diameter (cm)	Yield (kg/plant)
T_1= 1 kg dry biomass per m²	11.81±2.12[a]	11.59±3.24[b]	11.67±2.21a	25.12±2.74[a]
T_2= 1.5 kg dry biomass per m²	10.98±2.30[a]	8.65±2.94[c]	11.80±1.88a	24.25±3.41[a]
T_3= 2 kg dry biomass per m²	11.94±1.67[a]	14.04±5.98[a]	11.99±2.42a	25.84±4.3[a]
Control (No mulching)	9.60±2.30[b]	9.73±2.21[c]	8.38±1.34b	18.41±2.04[b]

Table 15.5. Effect of biomass mulching on soil chemical properties in bael

Treatments	Organic carbon (%)		Available nitrogen (kg/ha)		Available phosphorus (kg/ha)		Exchangeable potassium (kg/ha)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1= 1 kg dry biomass per m²	0.87± 0.18[a]	0.82± 0.19[a]	220.46± 33.18[a]	224.18± 32.19[a]	15.63± 2.47[b]	12.94± 2.24[b]	340.19± 52.38[a]	264.14± 44.63[a]
T_2= 1.5 kg dry biomass per m²	0.79± 0.14[a]	0.74± 0.14[a]	216.32± 36.34[a]	212.11± 34.29[a]	18.61± 2.19[a]	12.32± 1.76[b]	328.61± 51.11[a]	267.39± 36.54[a]
T_3= 2 kg dry biomass per m²	0.81± 0.18[a]	0.69± 0.21[a]	235.18± 31.19[a]	229.18± 33.63[a]	13.14± 2.14[c]	14.11± 2.81[a]	357.11± 51.74[a]	274.19± 42.35[a]
Control (No mulching)	0.61± 0.21[b]	0.62± 0.14[b]	208.61± 34.27[b]	228.36± 29.17[a]	16.14± 2.78[b]	8.32± 1.93[c]	264.45± 42.93[b]	256.89± 37.83[a]

Table 15.6. Effect of biomass mulching on soil chemical properties in mango

Treatments	Organic carbon (%)		Available nitrogen (kg/ha)		Available phosphorus (kg/ha)		Exchangeable potassium (kg/ha)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1= 1 kg dry biomass per m²	0.66± 0.14a	0.59± 0.13a	183.43± 34.81b	176.43± 38.81a	18.62± 5.95a	15.61± 2.80b	269.67± 62.02a	232.19± 44.11a
T_2= 1.5 kg dry biomass per m²	0.61± 0.11a	0.54± 0.08a	216.21± 45.40a	198.21± 35.67a	19.31± 1.93a	12.84± 1.41c	283.18± 53.80a	216.94± 45.52a
T_3= 2 kg dry biomass per m²	0.72± 0.18a	0.58± 0.19a	239.67± 50.52a	206.38± 63.97a	22.29± 3.34a	19.16± 4.41a	286.39± 41.45a	238.46± 52.46a
Control (No mulching)	0.48± 0.06b	0.46± 0.13a	186.44± 35.42b	178.63± 42.87a	15.16± 4.09b	14.32± 2.43b	209.46± 33.51b	194.57± 38.07b

16. Solar Energy Application

Irrigation Command Area of Small Capacity Solar Pumps in Eastern Region of India

Performance of different types of solar pumps, installed in Eastern region, were investigated to quantify groundwater output on daily, weekly and fortnightly basis to compute irrigation command area under prevailing solar radiation and groundwater depth regime. In Bihar, Chhattisgarh and Eastern Uttar Pradesh most of the pumps were found of small categories, i.e., 1.0 HP, 2.0 HP and 3.0 HP. Some of 1.0 HP and 2.0 HP solar pumps were centrifugal surface pumps while 3.0 HP solar pumps were solely submersible. Very few of them were of higher capacity viz. 5.0 HP, 7.0HP and 10.0 HP. High capacity pumps were mostly state owned and used as community tub wells for irrigation as well as for drinking water. During low insolation months solar irradiance was found to be in the rage of 200-500 W/m^2 while in remaining months it ranged between 200-980 W/m^2. The variation in solar irradiance in all the months shows a parabolic pattern (Fig. 16.1). The mean monthly averaged solar irradiation on a bright day for this region is ranged from 3.6-6.4 kWh/m^2/day.

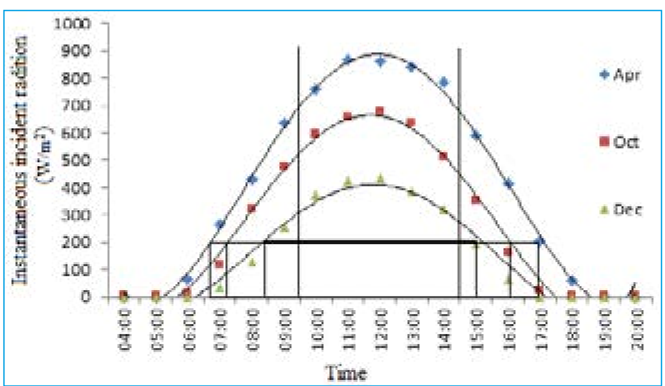


Fig. 16.1. Schematic diagram showing solar irradiance on a cloud free day in eastern region of India

The power output of solar array and the corresponding pump's discharge varied as solar irradiance varied over a day. A good discharge and delivery head of pump was found over a specific time band of the day. Operation threshold value of irradiance for low capacity solar pumps was above 200 W/m2. During low insolation month operating time band was 8.00 AM to 2.30 PM; whereas, in remaining months it was from 7.30 AM to 4.30 PM, if manually tracked solar panel was used. The most appropriate time band for crop irrigation was 9.00 AM- 2.30 PM. During this period both, manually tracked and fixed solar array gave almost same power output. A manually tracked solar array had its effectiveness over untracked array only before 9.00 AM and after 2.30 PM. During 9.00 AM to 2.30 PM solar pumps are more effective for irrigation, as during this period pumps discharge was good and waterfronts movement over soil surface was faster. This provided good irrigation efficiency, as transition time was less and deep percolation was to minimum.

A whole day operation of solar pumps equipped with manually tracking solar panel was found useful in maintain water in ponds, as during early and late hours of the day direct irrigating is not possible due to very low discharge. The abstracted volume of groundwater per day with manually tracked solar array over a fixed array was 20-23 percent more.

The water output from low capacity solar submersible pumps before 8.30 AM and after 2.30 PM with pumping head ≤10.0 m is reported in Table 16.1. In Eastern region small capacity solar pumps are prevalent, as in major parts the groundwater depth regime round the year remains ≤10 m bgl. Under this groundwater depth regime and prevailing solar radiation condition the estimated irrigation command area of 1.0 HP-0.9 kWp, 1.0 HP-1.2 kWp, 2.0 HP-1.8 kWp and 3.0 HP-3.0 kWp solar system, operated between 8.30 AM- 2.30 PM, were 0.52 ha, 0.77 ha, 1.07 ha and 2.01 ha, for vegetable crops and 0.67 ha, 0.99 ha, 1.38 ha and 2.57 ha for field crops, respectively.

Solar pump operation is confined to a limited period of the day; therefore, a limited area can be irrigated over a day. Thus, crops under solar pump must be grown in diversified mode under efficient cropping sequence to manage irrigation scheduling. Study showed that the farmers are not following beneficial crop sequences and desired diversification and therefore full potential of solar pumps are not exploited (Fig.16.2). This requires a change in established cropping sequences and crop diversification. Some of the suggested efficient cropping system for different climatic zones of Bihar is reported in Table 16.2.

Fig.16.2. Random cropping pattern under solar pump irrigation in Chhattisgarh and Bihar

Table16.1. Operational parameters solar submersible pumping system and estimated irrigation command area in Eastern region under prevailing groundwater depth regime

A	**Solar DC submersible pumps characteristics**												
1.	Pump capacity (Operating array)	1.0 HP (900Wp)			1.0 HP (1200Wp)			2.0 HP (1800Wp)			3.0 Hp (3000Wp)		
2.	Pumping head (m)	<10.0			<10.0			<10.0			<10.0		
3.	**Operation and discharge characteristics of solar pumps**												
4.	**Time band of operation**	**8.30 AM to 2.30 PM**											
5.	**Month**	**Daily discharge (m3/day)**											
i	Dec-Feb	15.9			24.8			31.2			64.8		
ii	Mar-April	26.5			39.2			54.4			102.4		
iii	May-July	20.4			32.0			44.8			84.0		
iv	Oct-Nov	24.4			36.8			53.6			92.0		
F	**Irrigated cropped area per day (ha)**												
G	Water application rate (cm)	**3.0**	**4.0**	**5.0**	**3.0**	**4.0**	**5.0**	**3.0**	**4.0**	**5.0**	**3.0**	**4.0**	**5.0**
i	Dec-Feb	0.06	0.04	0.04	0.08	0.06	0.05	0.10	0.08	0.06	0.22	0.16	0.13
ii	Mar-April	0.09	0.07	0.05	0.13	0.10	0.08	0.18	0.14	0.11	0.34	0.26	0.20
iii	May-July	0.07	0.05	0.04	0.11	0.08	0.06	0.15	0.11	0.09	0.28	0.21	0.17
iv	Oct-Nov	0.08	0.06	0.05	0.12	0.09	0.07	0.18	0.13	0.11	0.31	0.23	0.18
H	Command are for vegetables @ 3.0 cm depth at 7 days interval	**0.52**	-	-	**0.77**	-	-	**1.07**	-	-	**2.01**	-	-
I	Command are for field crop @ 5.0 cm depth at 15 days interval		-	**0.67**	-	-	**0.99**	-	-	**1.38**	-	-	**2.57**

Table 16.2. Efficient crops and cropping systems for Bihar to be included under solar pump irrigation

Zone I (North–West Gangatic Plains)					
Low and Mid Land			Up and Mid Land		
Kharif	Rabi	Summer	Kharif	Rabi	Summer
Rice	Wheat	Maize	Rice	Wheat	Mung bean
Rice	Sugarcane	-	Rice	Sugarcane	-
Rice	Potato	Maize	Rice	Potato	Maize
Rice	Tomato	Mung bean	Tobacco	-	Sesame
Rice	Makhana	Berseem	Rice	Makhana	Wheat
Rice	Potato	Sunflower	Soy bean	Lentil	
Zone II (North Eastern Gangatic Plain)					
Rice	Wheat	Maize	Rice	Wheat	Mung bean
Rice	Sugarcane	-	Jute	Maize	-
Jute	Potato	Maize	Rice	Potato	Maize
Rice	Tomato	Mung bean	Tobacco	-	Sesame
Rice	Makhana	Berseem	Rice	Makhana	Wheat
Jute	Potato	Mung bean			
Zone III (A) (South Eastern Bihar Plains)					
Rice	Wheat	Mung bean	Rice	Wheat	Cucurbits
Rice	Chickpea	-	Jute	Maize	-
Rice	Lentil	Maize	Rice	Potato	Maize
Rice	Chickpea	Mung bean	Tobacco	-	Sesame
Rice	Grass pea		Rice	Makhana	Wheat
Zone III (B) (South Western Bihar Plains)					
Rice	Wheat	Maize	Rice	Wheat	Mung bean
Rice	Sugarcane	-	Jute	Maize	-
Jute	Potato	Maize	Rice	Potato	Summer veg.
Rice	Tomato	Mung bean	Tobacco	-	Sesame
Rice	Makhana	Berseem	Rice	Makhana	Wheat

17. Farm Machinery

Ergonomic Evaluation of Axe

An ergonomic study of axe was carried out at ICAR-KVK Ramgarh, Jharkhand. Ergonomic and technical performance parameters were assessed for *axe* and based on the anthropometric data the handle was designed (Fig. 17.1 a&b). Wood handle in improved axe is helpful in increasing the output as it causes less friction and damage to hand skin as compared to bamboo handle which causes scratches on palm surface. The results indicated that the energy expenditure for modified axe was lower (9.33 kJ/min) than local axe (10.12 kJ/min). Compared to local axe, the modified axe reduced drudgery by 27.96% and increase in efficiency by 7.81%.

Ergonomic Evaluation of Spade

Before modification of spade, pain in waist was reported due to bending posture and improper handle diameter and length. The spade was ergonomically modified with respect to locally available spade and anthropometric data (Fig. 17.2 a&b). After modification, it reduced pain due to improved handle diameter and length thereby reducing drudgery. The results obtained were significant i.e., 38.33% reduction in drudgery and 8.39% increase in efficiency was observed when working with modified spade. Output was 5.44% more than the local spade.

Fig. 17.1 (a) Before modification

Fig. 17.2 (a) Before modification

Fig. 17.1 (b) After modification

Fig. 17.2 (b) After modification

Refinement, Demonstration and Distribution of Ergonomically Improved Wheel Hoe

The wheel hoe, developed by CIAE Bhopal, does not suit to short heighted tribal women workers in a hill and plateau region and damages plant due to uncontrolled movement. Based on the region-specific anthropometric data, the tool was modified in length, working height and width of a handle, etc. After modification there was 29.63% reduction in drudgery and 13.73% increase in efficiency over the existing wheel hoe.

Design and Development of Peripatetic Fish Vending Cart

A prototype of peripatetic fish vending cart was designed and fabricated (Fig. 7.3). The cart has water tank for live fish storage, an aerator operated by solar module, a box for frozen fish storage, cutting tools, tool box and dustbin. Rear wheel was replaced by one pair of tyre and tube and rim was fabricated from 20 mm MS hollow pipe to absorb additional load. Before fabrication, layout design was made for providing working facilities like space for live and frozen fish box; cutting and processing area; storage of water; utility space and disposal. The rear base platform of 1600 mm length and 1000 mm width was made using MS angles (40×40×5 and 25×25 ×5mm), flat (25×5 mm), MS rods (φ 8 mm) and GI sheet (16 gauge) etc and all the joints were welded. The work for providing facilities began from the rider seat. The utility/ tool box is made of ms sheet (53×30×35 mm); solar panel frame, (1090×660 mm). On the base frame a 100 ltrs Polyethylene insulated (PUF) box for keeping frozen fish and 250 L live fish container was placed. Three plastic tubs each 5 L capacity was placed at the rear end for waste disposal, which can be easily lifted when it is full. The cutting and processing areas of (650×500 mm) were made using 4 mm thick ACP sheet over base of MS structure to avoid fish contamination. Continuous aeration facilities were made through two solar PV panel (40 wp each) through storage battery, it will charge during the day and will be used during off sunshine hours. The driving mechanism is simple chain drive. The cutting knife which is popularly known as Boti was fixed with nut and bolt at the side of the processing area. The Boti was fitted in such a way that while fish dressing it should be in position and can be removed when not in use. The ergonomic evaluation and fish stock density determination is in progress. The fish vending card was demostrated to the RAC members of the institute for their feedback (Fig. 17.4).

Fig. 17.3. Prototype peripatetic fish vending car

Fig. 17.4. Demonstration of fish vending car

18. Livestock and Fisheries

Livestock

Characterization of Lesser Known Germplasms of Eastern Region

Dhanbadi Buffalo

A field study was conducted in Ranchi, Ramgarh, Hazaribagh, Giridih, Dhanbad and Bokaro districts of Jharkhand State to study the presence of unique animal populations reared by the farmers. It was found that the buffaloes reared in Dhanbad and Giridih had unique morphological features defining their own identity. Dhanbad buffaloes were found as medium sized animals with jet black coloured coat (Fig. 18.1). The horns were light grey coloured, loosely curved, oriented backward, upward and then curved in forward manner. The animals were medium producers with the average daily milk yield ranged from 4.0 kg to 10.0 kg per day. With respect to reproduction, the age at sexual maturity was found in the range of 3 to 4.5 years whereas the inter-calving interval was observed to vary from 18 months to 30 months. These animals were found to contribute significantly in the livelihood of farmers in their breeding tract in Jharkhand State.

Fig. 18.1. Dhanbadi buffalo

Jharkhandi cattle

The cattle found in the above districts in Jharkhand State were more or less similar in their morphological features with Medini cattle (Jharkhandi) which are already characterized. At most of the locations, these cattle were taken for community grazing in the nearby or little far-off vacant lands by a group of owners. Though the milk yield ranged from 1 to 3 kg per day, the cost of inputs spent by the farmers was almost nil other than the man-days expended by them in the form domestic manpower.

Besides cattle and buffaloes, the region witnessed the rearing of Palamu goats and a few unique duck populations. The detailed characteristics of these populations are being studied for further evaluation and registration.

Network Project on Buffalo Improvement

Institute has taken initiatives in Buffalo Improvement programme as a part of network project. A Murrah herd is being maintained with a total herd strength of 94 buffaloes with the objective of selecting elite bulls through a progeny testing programme. During the year, semen from five test bulls were used for artificial insemination on buffaloes and an overall conception rate of 53.6 per cent was achieved. Ultrasonography technique was utilized to verify the pregnancy at earlier stages in order to shorten the inter-calving intervals and improvement in related reproductive parameters. The Total Lactation Milk Yield, Standard Lactation Milk Yield and the Peak Yield achieved during the year were 2166.04±89.10 kg, 1824.42±63.04 kg and 9.93±0.43 kg, respectively.

Similarly, significant progress has also been made in the selective reproductive parameters. The Service Period, Dry Period and Inter-calving Intervals observed in the Murrah herd were 103.08±10.85 days, 99.90±12.62 days and 467.82±23.74 days, respectively. A total of 58.75 per cent of buffaloes were in milk during the year which was fetching the wet and herd average of 4.42 and 2.58, respectively. So far, under the project, 34 daughters are born and 3 daughters have completed their first lactation milk yield. Regular deworming and vaccination have been carried out and the herd mortality has been restricted to 6.38.

Effect of Genetic & Non-Genetic Factors on Prolificacy of Bengal Goat

The present work examines the ability of photo stimulated bucks to improve the male effect-induced reproductive response of young does over that induced by non-stimulated bucks. A 2×2 factorial experiment was designed, consisting of doe age and buck photoperiod treatments. During seasonal anoestrus, 34 does aged 10 (*n*=16) or 15 (*n*=18) months were subjected to the male effect on 10 April; half of each group was exposed to males rendered sexually active by prior exposure to 3 months of long days (16 h of light/day) from 31 October to 31 January 2021 (Photo bucks), and half to males maintained under the natural photoperiod (Control bucks). Long day light (300 lux) was provided by extra light beyond natural day length light. The testosterone concentration decreased rapidly after the start of the photoperiod treatment, but began to increase after its end, and did so for about 3 weeks (Fig. 18.2). In contrast, the control bucks showed low testosterone concentrations. No significant difference in frequency of oestrus behavioural pattern between the groups was observed however the maximum frequency of oestrus behaviour was tail fanning followed by bleating and mounted by others, frequent micturition, buck clustering and buck teasing was recorded. The intervals 'introduction-oestrous' or 'introduction-first elevation of the progesterone concentration', were not modified by doe age, buck photoperiod treatment or their interaction. The percentage of females showing oestrus was higher in the does exposed to photo bucks (75% *v*. 62.5% for those exposed to control bucks) in 10 month old does and (100% v. 66.67%) in 15 months old does. The does in contact with the photo bucks showed a better percentage of females showing oestrus irrespective of doe age after introduction of males.

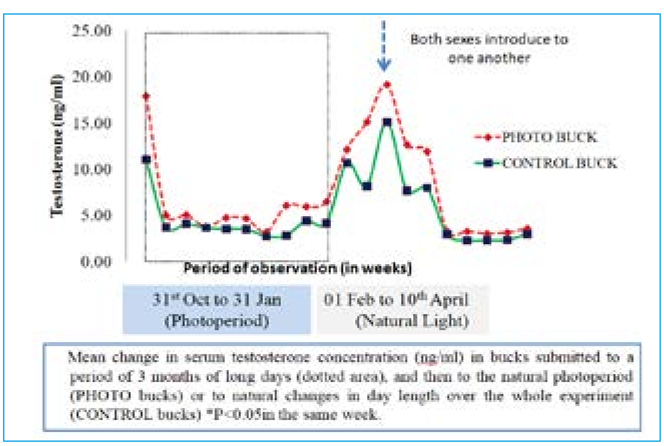


Fig. 18.2. Serum testosterone concentration

AICRP on Goat Improvement

All India Coordinated Research Project on Goat Improvement was started at ICAR Research Complex for Eastern Region, Patna in the year 2018-19. The centre, being at initial years, attention was paid on strengthening the five clusters initially established, building rapport with the goat farmers in the centers and consolidation of activities. During the year, the population growth in the selected villages expanded to the tune of 135.56 % with new addition of breed able does and new births. The mortality was controlled within 2.1 % due to comprehensive efforts of vaccination, deworming, timely therapeutic interventions and awareness programme. The average body weight at 3 and 6 months of age was recorded at 4.19 ± 0.14 kg and 6.21 ± 0.24 kg, respectively. Average lactation milk yield was recorded as 17.92 ± 3.56 kg at 60 day and 20.88 ±3.78 kg at 90 d of lactation. A total of 1068 does were available for breeding (Fig. 18.3). Tupping percentage was recorded at 89.70 while breeding efficiency was recorded at 99.27% on the basis of does tupped. A total of 2575 animals were dewormed, 1630 animals were vaccinated and dipping of 995 animals was done under the project (Table 18.1). The unit also organized two training programme for tribal and SC farmers beside 12 awareness programme and 15 animal health camps. Significant increase in the socio-economic conditions of goat farmers registered under the project was also observed.

Fig. 18.3. Selected breedable does in the project site

Table 18.1. Year wise health control measures of goats undertaken in the project sites

S. No.	Prophylactic Measures	2018-19	2019-20	2020-21	2021-22
1	Deworming	1521	1746	2011	2575
2	Vaccination FMD & HS	502	750	825	1025
3	Vaccination PPR & ET	1056	1306	2600	1630
4	Dipping	502	750	825	995
5	Coccidio-stat (Monension Feeding)		500	588	630

Development of Meat and Egg Strains of Duck Germplasms for Backyard System of Farming

With an objective of developing a duck strain suitable for backyard farming, a population of Maithili ducks were crossed with White Pekin drakes and the cross produced 32 F1 generation ducklings. A total of 5 White Pekin males which were genetically superior in their body conformation and body weights over their contemporaries were selected to act as parental stock. From F1 generation, 3 superior males were selected and they were interbred with their half-sibs to produce interbred ducklings. Evaluation of performance traits in the F2 siblings are underway. Initial findings show that there are marked improvements in the growth and body weight gain in F2 generation. Subsequent selection and breeding may result in unique strain which may be suitable for backyard system of rearing in the eastern region.

Characterization & Evaluation of Duck Germplasm in Eastern Region

Four hundred eleven ducks (70 from Bihar, 71 from Chhattisgarh and 90 each from Bihar, Jharkhand &West Bengal) were studied for certain economic traits. The adult weight for Bihar, Jharkhand, Chhattisgarh, Odisha and West Bengal ducks were 1482.70±12.45, 1573.90±19.76, 1555.4±12.73, 1597.30±29.04 and 1513.50±17.94 g, respectively. At 0 to 8 weeks of age significantly higher body weight gain was recorded in Odisha duck among all the five duck germplasm. The respective feed conversion ratios were found to be better in Odisha (3.62±0.07) and Chhattisgarh (3.99±0.10) duck. The average age at first laying (days) was 191.12±1.63, 187.62±2.20, 187.62±1.58, 178.40±1.77 and 182.73±1.74 for Bihar, Jharkhand, Chhattisgarh, Odisha and West Bengal, respectively. Annual egg production of West Bengal ducks was comparatively more (84.03±1.49).

Assessing genetic variability in duck of eastern states

To explore phylogenetic relationship based on mitochondrial DNA sequence among duck found in eastern India, mitochondrial DNA sequencing followed by genome assembly and annotation was done for ducks of White Pekin (WP), Khaki Campbell(KC) and Maithili (M) breed. Mitochondrial genome NC_009684.1 was used from reference assembly with the accession number GCA_015476345.1 ZJU1.0 to guide the assembly. The GC content in mitochondrial genomes of three breeds- White Pekin (WP), Khaki Campbell (KC) and Maithili (M) breed, were found to be 48.64%, 47.6% and 46.59%, respectively (Fig. 18.4).

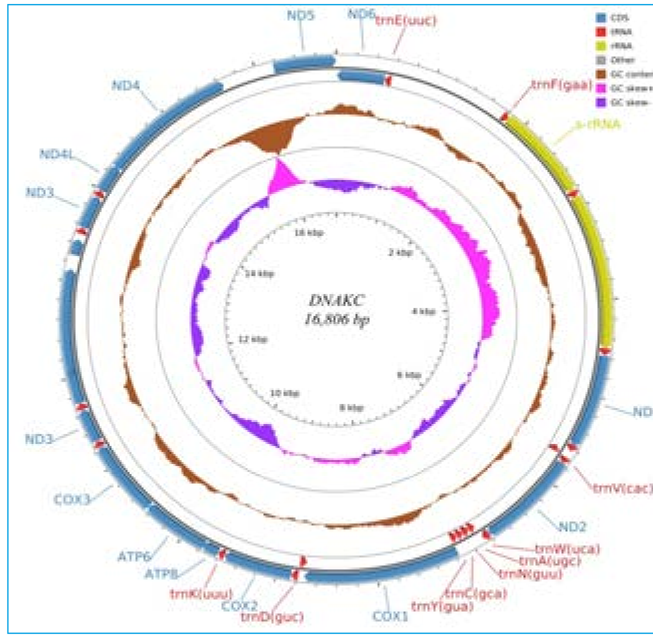


Fig. 18.4. Annotated mitochondrial genome of Khaki Campbell duck

Model Project on Backyard Poultry, Livestock, Vermifarming and Moringa Integration

The project on "Model Project on Backyard Poultry, Livestock Vermifarming and Moringa Integration started in the year 2021 under RKVY. The indigenous (17 Sahiwal) and crossbred (21 Holstein) cows present at Cattle & Buffalo unit of ICAR-RCER, Patna, were selected for quantification of dung and urine and utilization in vermifarming and as liquid manure (Table 18.2). Productive performance of Sahiwal and crossbred Holstein Friesian cattle was recorded (Table 18.3). *Moringa oleifera* on field bunds was planted (Fig. 18.5). Hundred indigenous germplasm of Kadaknath birds were stocked in the existing structure of backyard unit (Table 18.4). Earthworm *(Eisenia fetida)* production in smaller was initiated in existing portable vermibed at institute and fed to the poultry after multiplication.

Fig. 18.5. Kadaknath birds in backyard

Table 18.2. Quantity and physical properties of fresh urine and dung of cattle

Particulars	Parameters	Sahiwal	Crossbred HF
Dung	Quantity (kg/cattle/day)	16.57±0.29	15.05±0.22
	pH	7.24±0.17	7.56±0.19
	Dry matter %	77.67	78.20
Urine	pH	7.66±0.11	7.66±0.13

Table 18.3. Productive performance of Sahiwal and crossbred Holstein Friesian cattle

Parameters	Sahiwal	Crossbred HF
Lactation length (d)	252	315
Lactation yield (l)	2207	3128
Birth wt. (kg)	16.2	26.8
Peak milk yield (kg/d)	15.0	27.0

Table 18.4. Growth performance (g) of Kadaknath birds upto 12 weeks of age

Sex	Age in weeks		
	4 weeks	8 weeks	12 weeks
Male	449.5±3.39	555±11.25	927.5±16.57
Female	354.0±12.38	429.63±13.63	643.96±28.77

Molecular Epidemiology and Therapeutic Management of Bovine Theileriosis

Haematological examination of 198 bovine samples indicated anaemia with haemoblobin level varying from 3.4 to 12.0 g% and RBC count was towards lower range of normal counts. The Giemsa stained blood smear examination indicated 30.81% positivity for infection of tick borne haemo-parasitic infection with highest for Theileria spp, followed by Analplasma and Babesia pathogen. Whole genomic DNA was extracted using commercial kit and stored for further study. Fraction of infected cattle (39.34%) had mixed infection of both *Theileria* spp and *A. marginale* parasite. Apart from this, attempt was made to subtype the prevailing oriental theileriosis in the region caused by infection of *T. orientalis*. Report suggests that there are 11 subtypes of this organism and out of which only two (Subtype chitose and ikeda) are considered pathogenic for bovine. *T. orientalis* positive samples were explored for possible subtype circulating in the population. Our reports based on current activity suggests presence of only chitosi subtype in the region based on primer specific amplification at 831bp.

Studies on Development of Early Pregnancy Diagnosis Method in Buffalo

Investigation was carried out to employ whole blood sample as an alternate to PBMC (peripheral blood mononuclear cells) for studying expression profiling of select ISGs – ISG 15(Interferon stimulated gene 15), MX 1 (Myxovirus resistance 1) and MX 2 (Myxovirus resistance 2) during peri- implantation period in artificially inseminated dairy buffaloes using sybr green chemistry based quantitative real time reverse transcription PCR. Our results showed, transcriptional abundance of ISG-15 and MX2 genes were up regulated during peri-implantation period in buffaloes, but MX1 gene was found to be downregulated post day 18 of artificial insemination. Fold change in expression level between day 12 and 15 post AI did not vary significantly for ISG 15 and MX2 gene. Since the transcriptional abundance of all genes in whole blood sample, exhibited same trend as reported by previous researchers, in their studies, with the use of PBMC, henceforth, we suggest that whole blood can be successfully used as PBMC surrogate for expression profiling of genes involved in maternal recognition of pregnancy (MRP).

In continuation of our previous findings, suggesting expression profiling of chemokine genes CCL 8 (C-C motif chemokine 8) and CXCL10 (C-X-C motif chemokine 10) as indicator of pregnancy establishment in dairy buffaloes, further study was done to examine the effect of parity on their expression profile. We found insignificant variation in transcriptional abundance of both the genes among primiparous and multiparous animals (Fig. 18.6 and 18.7). Therefore, it can be concluded that, expression

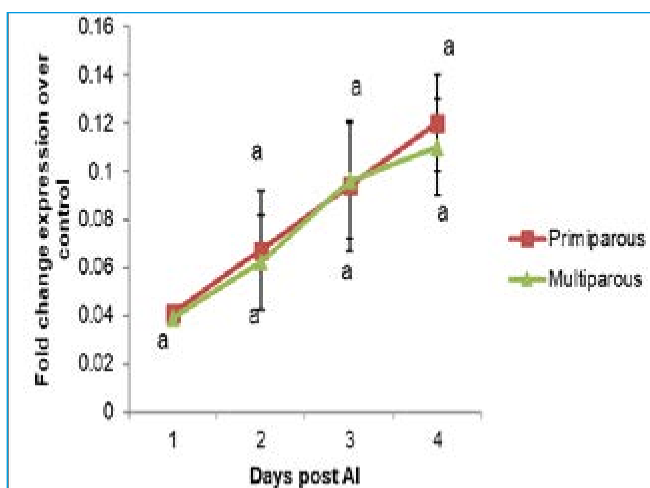


Fig. 18.6. Effect of parity on expression profile of chemokine CCL8 in pregnant buffaloes. Minimum level of significance was set at 95%. Each point represents Mean ± SEM. Points with different superscript denotes significant difference ($P < 0.05$)

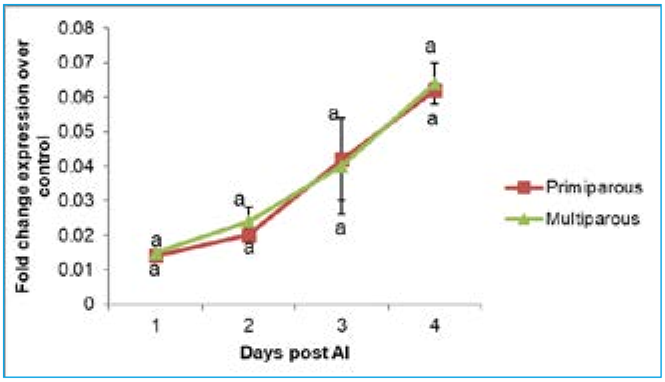


Fig. 18.7. Effect of parity on expression profile of chemokine CXCL10 in pregnant buffaloes. Minimum level of significance was set at 95%. Each point represents Mean ± SEM. Points with different superscript denotes significant difference ($P < 0.05$)

profiling of CCL8 and CXCL10 can be used as signature for pregnancy establishment irrespective of the parity status of animal.

Outreach Programme on Zoonotic Diseases

Study was conducted to identify and characterize the Shiga toxin producing *Escherichia coli* (STEC) in cattle and buffaloes in Bihar. Sero-prevalence study was conducted to know the prevalence of brucellosis. Random Serum was collected from 3 districts in Bihar to study the prevalence of Brucellosis in bovine species. The method to study the prevalence was by use of Rose Bengal Plate antigen procured from Indian Veterinary Research Institute, Izatnagar, Bareilly. A total of 4 samples (2.75%) from a total of 145 bovine samples revealed sero-positivity by Rose Bengal plate test.

Prevalence, identification and molecular characterization of Shiga toxin producing *Escherichia coli* (STEC) in Bihar.

A total of 145 faecal samples and milk samples were collected from cattle and buffaloes and used for isolation of *E. Coli* bacteria on laboratory growth media. PCR was done with partial 16 S gene primer to confirm the *E. coli* organisms identified by culture characteristics and biochemical tests. The serotypes identified based on Somatic Antigen typing have been given in (Table 18.5). PCR protocols were standardised to identify Shiga toxin 1(STX 1) and Shiga toxin 2(STX 2) producing *E.coli*. STX 1 producing E. Coli cultures yielded 614 bp product in PCR (Fig. 18.8) whereas STX 2 producing *E. Coli* produced 779 bp (Fig. 18.9) amplicons. Using this protocol the isolates were typed based on the Shiga toxin production and type of Shiga toxin produced. Out of 101 isolates, 50 isolates were found to be positive for Shiga toxin production (49.5%). However the Shiga toxin production potential was not dependent on the somatic antigen based *E.coli* serotypes as is evident from (Table 18.6). It is evident from this study that animal faeces is source of STX producing *E. coli*. Such organisms can infect human population to produce serious diseases.

Table 18.5. The serotypes identified based on Somatic Antigen typing

Sl. No.	Serotypes	No. of isolates	Sl. No	Serotypes	No. of isolates
1.	O2	1	11.	O114	1
2.	O7	4	12.	O118	3
3.	O9	1	13.	O119	7
4.	O17	1	14.	O120	13
5.	O18	8	15.	O121	1
6.	O20	7	16.	O126	2
7.	O26	8	17.	O134	1
8.	O98	10	18.	O135	2
9.	O101	5	19.	O149	2
10.	O111	8	20.	UT	14

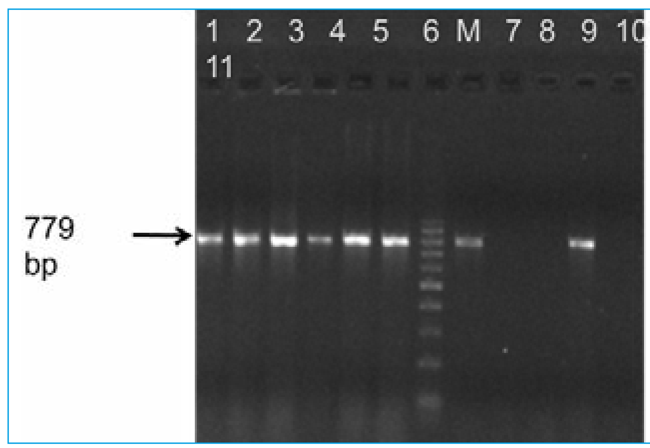


Fig. 18.8. Gel Electrophoresis for PCR with primers STX 1F and R Lanes 1-10 : Positive samples, Lane M 100 base pair marker

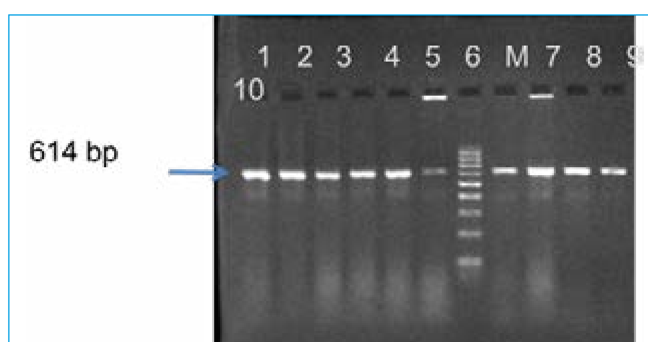


Fig. 18.9. Gel Electrophoresis for PCR with primers STX 2F and 2R Lanes 1-7 and 10 : Positive samples, Lanes 8-9 negative samples. Lane 11 : negative control, M 100 base pair marker Control, M: 100bp marker

Table 18.6. Shiga toxin production potential of different ***E. coli*** serotypes identified in the study

Sl. No.	Types of Shiga toxin (STX) produced	*E. coli* Serotypes producing the toxin
1.	STX 1	O7, O17, O26, O101, O111, O119, O120, Untypable serotypes
2.	STX 2	O20, O26, O98, O101, O111, O120, O126, Untypable serotypes
3.	STX 1 & STX 2	O7, O9, O18, O20, O26, O98, O101, O120, O149 untypable serotypes
4.	None	O2, O7, O18, O20, O26, O98, O101, O111, O114, O118, O119, O120, O126, O134, O135, Rough, Untypable serotypes

Exploring Genetic basis of Mastitis Resistance in Livestock

A total of 95 cattle and 22 buffalo milk samples were screened for subclinical mastitis by California mastitis test. Out of these 22 cattle and 5 buffaloes were found to be suffering from subclinical mastitis. About 5 ml of blood were collected from animal suffering from clinical/subclinical mastitis. Genomic DNA and total RNA was isolated from these blood samples. First strand of cDNA was prepared from total RNA. Primers were designed for amplification of antimicrobial protein gene like lactoferrin and TLR (Fig. 18.10). Milk samples were processed for bacterial isolation. It yielded a total of 32 bacterial isolates comprising of *Staphylococcus aureus* (12), *Staphylococcus spp.* (08), *Streptococci spp*. (08), *Escherichia coli* (02) and others (04). They have been identified based on colony characteristics, staining and their morphology. *S. aureus* isolates were confirmed by amplification of thermo nuclease gene by PCR.

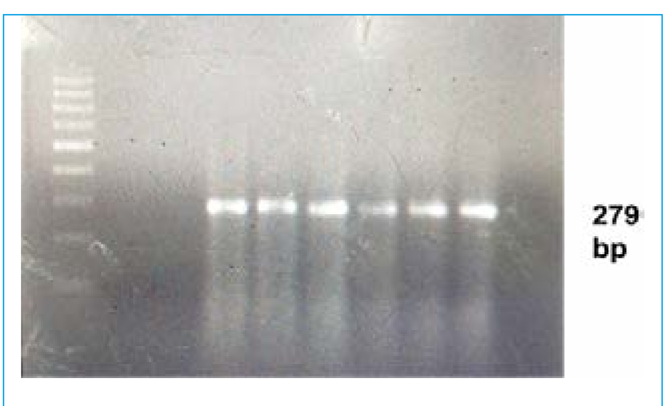


Fig. 18.10. PCR amplification profile of *S. aureus* isolates Lane 1: DNA ladder, lane 2: negative control, lane 3: known negative (*E. coli* DNA as template), lane 4: Positive control, lane 5-9: *S. aureus* isolates positive for 279 bp amplicon of thermonuclease gene

Generation of CRISPR mediated bi-allelic BMP15 gene edited quality goat embryos

Generation of CRISPR mediated bi-allelic BMP15 gene edited quality goat embryos” Caprine embryos containing BMP-15 gene mutations were produced and the mutation detection was done by T7E1 assay. The efficiency of editing of embryos for $FecX^{Gr}$ and $FecX^{O}$ was 58.90% and 50.94%, respectively. The mono and bi-allelic percentage for $FecX^{Gr}$ edited embryos were 79.17%, 20.83% respectively as revealed in the in-vitro cleavage assay. Similarly the mono and bi-allelic percentage in $FecX^{O}$ edited embryos were 76.54% and 23.46%, respectively. BMP15 mutations ($FecX^{Gr}$ and $FecX^{O}$) in sheep are known for increasing rate of ovulation in sheep. Such mutation generated in goat embryos in our experiment, if successfully transferred in suitable recipient may produce caprine species with enhance ovulation rate.

Fisheries

Production of *Anabas testudineus* in Biofloc System of Aquaculture

The growth performance of commercially important *Anabas testudineus* under the high stocking density and low feeding was carried out in the Biofloc system (Fig. 18.11),where all the waste nutrients of fish were recycled back by the help of microbes. The same amount of lime, salt, carbon source, nitrogen source and probiotics were used to prepare the desired concentration of flocs in each Biofloc tank. The different stocking densities @ 100/$m^2$and 60/m^2 and 2 to 4% feeding was maintained throughout the experiment. The growth performances under the high stocking density (Treatment T_1) @ 60/m^2 with low feeding (2%) showed better growth performances than high stocking-high feeding treatments. The specific growth

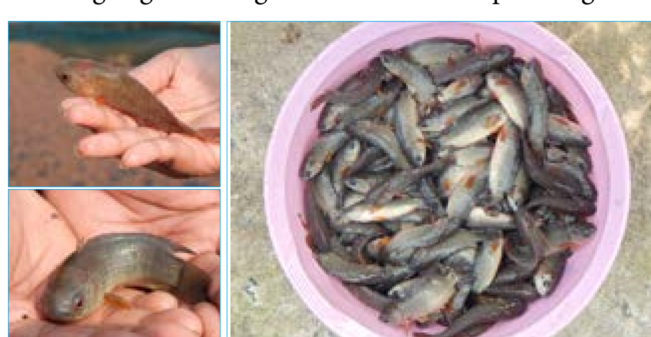


Fig. 18.11. *Anabas testudines* (Kawai) in Biofloc culture experiment

rate, mortality rate and FCR for T_1 was significantly better than T_2 and T_3 (Fig. 18.12). The highest mortality, 24% was found in control, whereas treatments were shown moderate 6-7% mortality.

All the desired water quality parameters were analysed and found within acceptable limits for fish culture in Biofloc system.The floc concentration was also regularly analysed and maintained by the addition of carbon source (jiaggery). There was no significant difference found in haematological parameters (Table 18.7) in control and floc conditions. Time series plankton density under the floc treatments were analysed and given in Fig 18.13 About 37 species of plankton/algae were identified from the Biofloc water (Table 18.8) throughout the culture period.

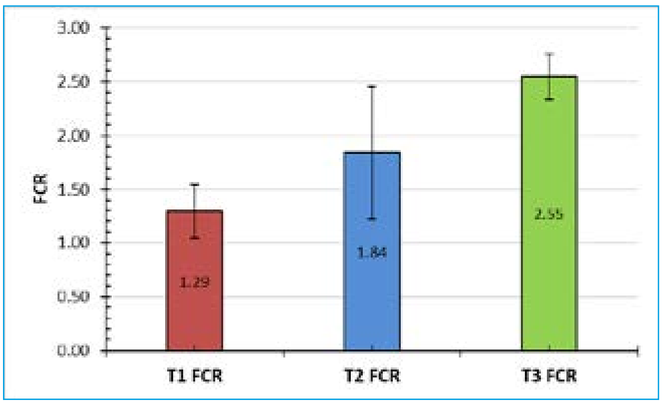


Fig. 18.12. The specific growth rate, mortality percentages and FCR of Kawai under the Biofloc experiment

Table 18.7. Haematological parameter of Kawai fish under Biofloc and control conditions

	WBC (10^3/ mm^3)	RBC (10^6/ mm^3)	Hb (g/ dl)	*PCV (%)	*MCV (fl)	*MCH (pg)	MCHC (g/dL)
Control	140	2.80	8.00	24.0	85.7	28.6	33.0
Biofloc	150	2.23	6.13	18.6	84.7	27.2	32.5

***PCV: Packed cell volume % * MCV: Mean corpuscular Volume(fl)**
***MCH: Mean corpuscular Hemoglobin (pg)**

Table 18.8. Identified plankton/algae species from Biofloc system

Sr No.	Plankton	Nos.
1	Diatoms	10
2	Green Algae	14
3	Copepod	7
4	Rotifer	6
Total		37

Induced Breeding and Seed Production of Biofloc Reared Kawai, *Anabas testudineus*

Kawai is an important air-breathing fish and considered one of the potential species for aquaculture in India. However, due to non-availability of the quality seed and proper grow-out technology, this species is not much popular for aquaculture among the fish culturist. The breeding season of Kawai starts from April and continues until late August with a peak in May-June.

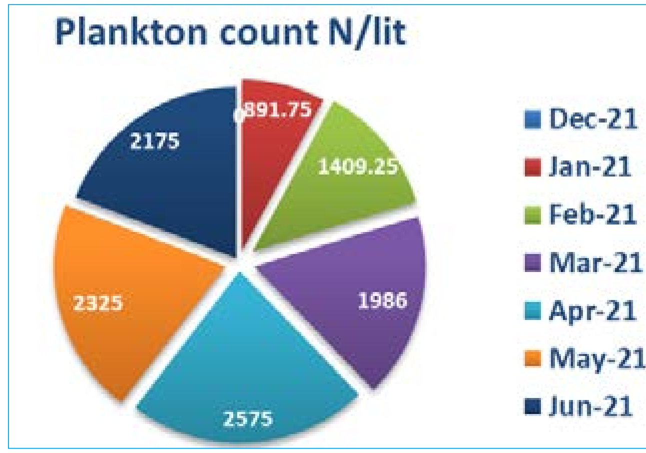


Fig. 18.13. Temporal planktonic density of the Biofloc system

During the monsoon season around 38 mature brooders (22 male; 16 female) were collected from Biofloc experiment system. A Wova-FH synthetic inducing hormone @ 0.1-0.2 ml/kg (male) and 0.3-0.4ml/kg (female) were injected using an intramuscular injection to all mature brooders and injected fishes were released back into a breeding tank. It was observed that spawning starts after 10-12 hrs and hatching 24-26 hrs of hormone injection. The total fecundity around 380-400 nos/g of body weight and 66% fertilization, and 70% hatching of fertilized eggs were obtained. A systematic induced breeding technique of Kawai is given in (Fig. 18.14). The seeds of Kawai again stocked in biofloc system and more than 2000numbers of seed distributed to the state fisheries department of Bihar (Fig. 18.15).

Formulation of Mineral Mixture for Indian Major Carp (IMC) Based on Soil-Water and Fish Continuum

A study was undertaken with an aim to investigate the effect of mineral mixture on the growth performance of Mrigal (*Cirrhinus mrigala*). A 60 day feeding trial was conducted at ICAR-RCER, Patna with four different treatments. T_0- Rice bran (50%)+Mustard oil cake (50%),

Fig. 18.14. Induced breeding technique of Kawai, *Anabas testudineus*

Fig. 18.15. Seed distribution of induced bred Kawai, *Anabas testudineus*

T_1-Rice bran (49.5%)+Mustard oil cake (49.5%)+Mineral mixture (1%), T_2-Rice bran (49%)+Mustard oil cake (49%)+Mineral mixture (2%) and T_3-Rice bran (48.5%)+Mustard oil cake (48.5%)+Mineral mixture (3%) with three replicates each. The fishes were stocked @ 10 fish per tank having average size of 20g. Better average growth performance was observed in treatment T_4 with 3% mineral mixture inclusion (Fig. 18.16). Average daily growth, specific growth rate and percentage weight gain in fish were best in treatment T4 with 3% mineral inclusion (Fig. 18.17). Water quality parameters like DO, pH, alkalinity, hardness, ammonia, nitrite and phosphate was within acceptable range.

Economic Feasibility of Integrated Prawn cum Fish Farming in Polyculture System in Eastern Region

An earthen pond of 1000 m^2 area were used for conducting the experiment at ICAR-RCER, Patna. The pond was sundried completely followed by water filling and liming @ 15 kg. The pond was initially manured @ 100 kg of cow dung and a mixture of rice bran (5kg), agrimin powder (100g), DAP (0.5kg) etc. To facilitate the growth and reduce the mortality of prawns hide out pipes were provided. Stocking was done in the month of March @5000 nos. of IMC and 20,000 nos. of prawn/ha (0.005g) seeds, respectively. Feeding was done with starter 1 feed with 100% body weight of prawn till they attained the body weight of 1 g. Floating feed @ 4% of the body weight was used for feeding of IMC. After the prawn reached 4-5g, polyculture sinking pelleted feed was offered according to the body weight of the prawn. For growth analysis and health management of fishes and prawn, monthly length-weight data were collected (Fig. 18.18). All the water quality parameters were estimated within the acceptable limit (Table 18.9).

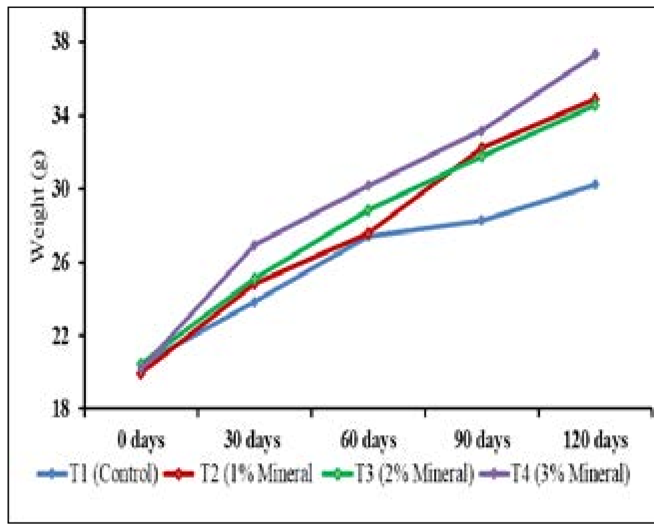


Fig. 18.16. Average growth performance of Mrigal in different treatments

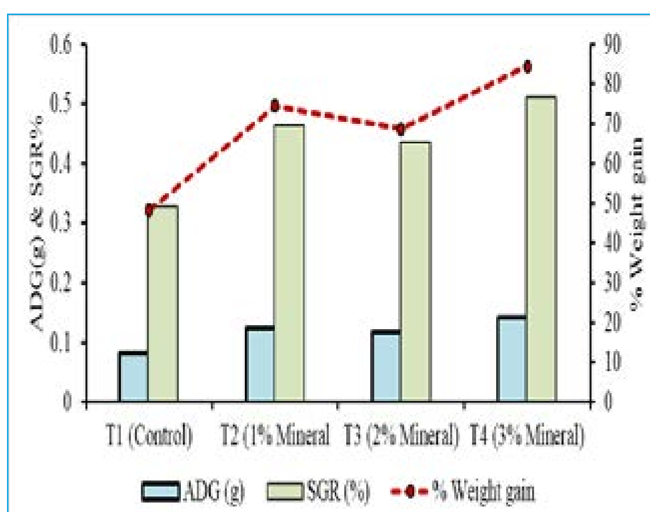


Fig. 18.17. Average daily growth, specific growth rate and percentage weight gain of Mrigal in different treatments

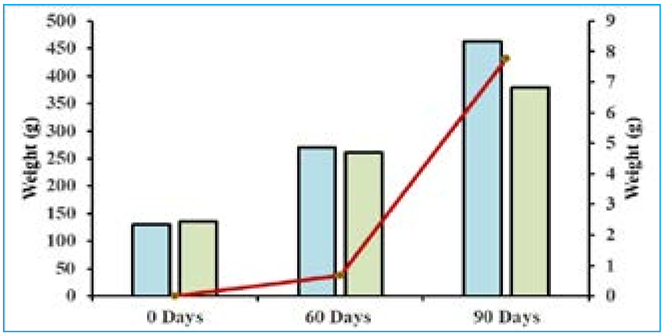


Fig. 18.18. Growth of catla and rohu in polyculture system

Table 18.9. Water quality parameters estimated from polyculture system.

Parameters	mg/l
Dissolved oxygen	6.11±0.22
pH	7.64±± 1.4
Alkalinity	137.2±5.48
Hardness	146.0±5.11
Ammonia	0.03±0.002
Nitrate	0.19± 0.04
Phosphate	0.71± 0.029

Development of *Labeo gonius* Brood Stock

Labeo gonius is an important minor carp and available across eastern region. Seed is the major problem of this species for culture. Hence an attempt was made for the development of brood stock and standardization of the breeding technology.

For the study, healthy fingerling (156.8±2.08 mm, 39.79± 1.53g) were stocked in cemented tank @ 1/m^3, 2/m^3 and 3/m^3. Round the clock aeration was provided in all the tanks from a centralized air blower.

From the study it was observed that there was significant effect of stocking density on weight gain of *L. gonius*. Best performance was recorded when reared in 1/m^3 followed by 2/m^3. Average daily gain, percentage weight gain and specific growth rate of *L. gonius* were also better when reared in 1/m^3 (Fig. 18.19 & 18.20). Hence it is recommended that space requirement of brood stock fish of *L. gonius* should be at 1 no./m^3.

A preliminary breeding trial was taken from the brood stock developed. Total of 9 male and 6 females were attempted in three occasions at the ratio of 2:3 (F: M), with an average weight of male and female were 179.77 and 216.6g, respectively. Hormone Wova-FH was used for the experiment at the rate of 0.7-0.8ml/kg and 0.3-0.4 ml/kg body weight for female and male, respectively. Spawning was observed at 10-12 h after injection. Fecundity was 80-90 nos/ g of body weight. Fertilization and hatching was 79.09% and 70.03% of fertilized egg, respectively. Egg diameter and hatchling length was 2.5-2 mm and 6.2-6.8 mm (1.5-1.9mg), respectively.

Resource Assessment and Management Framework for Sustainable Fisheries in Selected Wetland

Ichthyofauna biodiversity was assessed in selected wetlands in Bihar with the aim to study the population

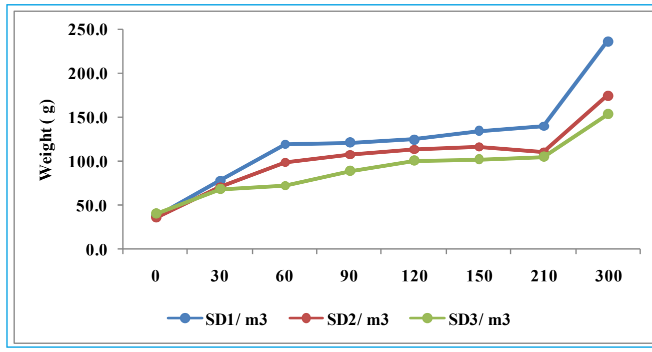


Fig. 18.19. Growth performance of *L. gonius* fry at the end of 300 days of culture

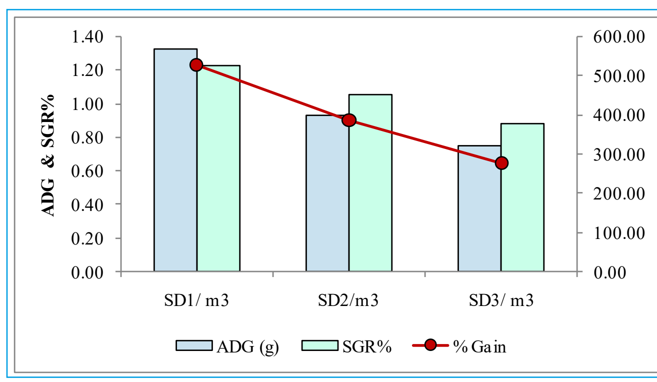


Fig. 18.20. Average daily gain, specific growth rate and percentage gain of *L. gonius* fry at the end of300 days of culture

parameters of selected species, to estimate different soil and water quality parameters prevailing in selected wetlands of Bihar and to record the different fisheries management strategies existing in selected wetlands in Bihar. A wetland from Khagaria district of Bihar namely, *Kasaraiya maun* was selected to understand fisheries management practices in view to exploration of maximum sustainable yield. Kasaraiya maun (N25.492937˚; E 86.619178˚) is located in Khagaria district and is typically in *Sickle shaped* (Fig. 18.21). Kasariaya maun is expanded in about 6 km from NH 31 in western side to Farreh North-eastern side covering area 75 hectare with average depth of 20 feet even in summer season. The half of the maun has very high depth (50 feet), which is suitable for installation of cage for aquaculture. The rest its half portion is shallow depth, where pen culture, integrated farming an seed rearing can be done. This maun may be the deepest wetlands in Bihar. Approximately 50-60% of the lake is covered by macrophytes. Even though, daily average catch of fish was estimated 80-100 kg. Fishing is carried out using seine net (Mahjal jal, Chhatti Jal) with the operation of traditional boat, locally known as *dingy*.

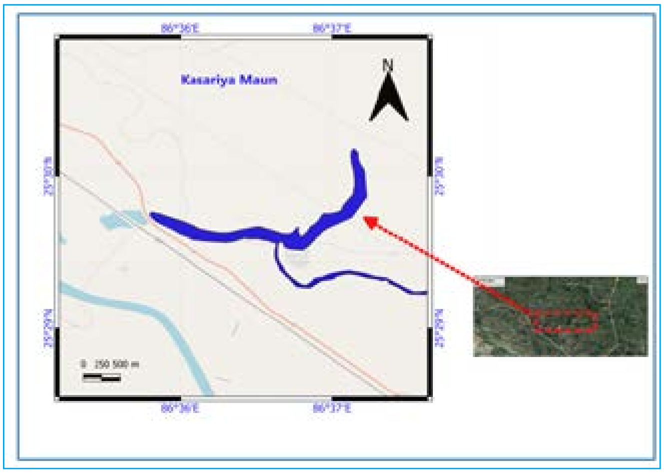


Fig. 18.21. Map shows the location of Kasariya maun

On preliminary study, total 27 fish species was identified in this *maun* (Table 18.10). The maximum species was belonged to family Cyprinidae (33.3%), while Channidae (11.1%) shared three species, two species by each family bagridae, ambassidae and Schilbeidae with share of 7.4% and one species was belonged to each family like Nandidae, Belonidae, Clupeidae, Heteropneustidae, Anabantodidae, Siluridae, Gobiidae, Tetraodontidae, Notopteridae with sharing of 3.7% each. A higher species diversity was found in post-monsoon season compare to monsoon. The variation of water quality of Kasaraiya maun was studied, which indicated that pH, dissolved oxygen (DO), alkalinity, hardness, ammonium, nitrite and phosphate was higher in post-monsoon season in comparison to monsoon season (Table 18.11).

National Surveillance Programme for Aquatic Animal Diseases (NSPAAD) in Bihar

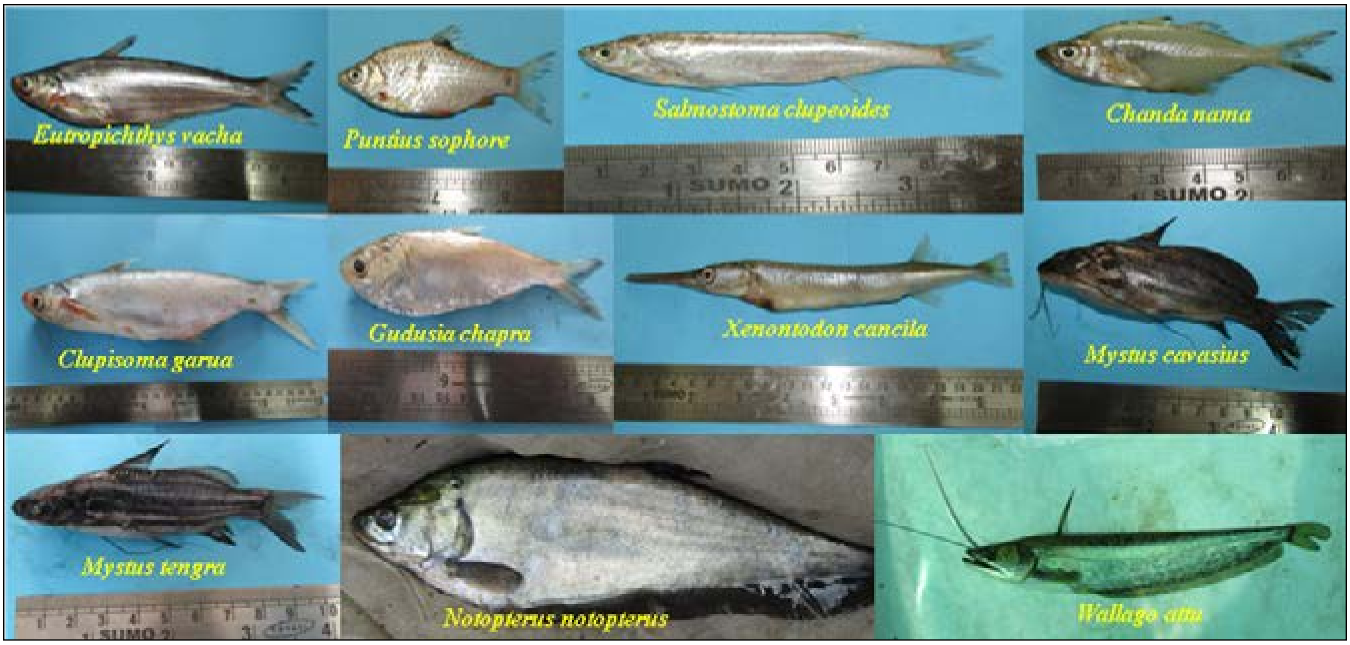
Data were collected from different districts of Bihar like Khagaria, Vaishali, Motihari, Patna, Sitamarhi and Nalanda and collected water and fish samples for analysis from the fish culture ponds as well as information related

Table 18.10. Variation in water quality parameters in Kasaraiya Maun, Khagaria

Seasons	Parameters							
	Temperature (˚C)	pH	Alkalinity ($CaCO_3$ mg/l)	Hardness (CaCO3 mg/l)	DO (mg/l)	Ammonium (mg/l)	Nitrite (mg/l)	Phosphate (mg/l)
Monsoon	32.70 ±0.57	7.44 ±0.30	133.57 ±38.73	132.25 ±26.13	7.10 ±1.65	0.17 ±0.05	0.07 ±0.02	0.02 ±0.01
Post-monsoon	18.97 ±0.90	7.50 ±0.21	254.80 ±3.63	200.80 ±14.25	7.80 ±1.98	0.986 ±0.93	0.11 ±0.02	0.11 ±0.16

Table 18.11. List of identified species of fish in Kasaraiya maun

SN	Species	Family	SN	Species	Family
1	*Catla calta*	Cyprinidae	15	*Chanda nama*	Ambassidae
2	*Labeo rohita*	Cyprinidae	16	*Parambasis baculi*	Ambassidae
3	*Cirrhinus mrigala*	Cyprinidae	17	*Clupisoma garua*	Schilbeidae
4	*Cirrhinus reba*	Cyprinidae	18	*Eutropiichtys vacha*	Schilbeidae
5	*Ctenopharyngodon idella*	Cyprinidae	19	*Nandus nandus*	Nandidae
6	*Labeo gonius*	Cyprinidae	20	*Xenentodon cacila*	Belonidae
7	*Labeo calbasu*	Cyprinidae	21	*Gasdusia chapra*	Clupeidae
8	*Salmostoma clupeoides*	Cyprinidae	22	*Heteropneustes fossilis*	Heteropneustidae
9	*Puntius sophore*	Cyprinidae	23	*Anabas testudineus*	Anabantodidae
10	*Channa striatus*	Channidae	24	*Wallago attu*	Siluridae
11	*Channa orientalis*	Channidae	25	*Acetrogobius sp.*	Gobiidae
12	*Channa marulius*	Channidae	26	*Tetradon cutcutia*	Tetraodontidae
13	*Mystus tengara*	Bagridae	27	*Notopterus notopterus*	Notopteridae
14	*Mystus cavasius*	Bagridae			



to fish culture activities. Fish samples were collected and brought to the laboratory. Fish tissues from farmer's field were screened (DNA, RNA, cDNA and PCR) to detect the presence of target pathogen i.e. Koi Herpes Virus (KHV) and Spring Viraemia of Carp Virus (SVCV). None of the samples was found to be PCR positive for KHV and SVCV (Fig. 18.22 & 18.23). Under passive surveillance we could address some of the disease problems reported from farmer. There was frequent occurrence of *Argulus* sp. and *Lernaeae* sp. in carps in many fish fonds. During this year, we could conduct 9 awareness programmes in different districts of Bihar with special focus on fish disease management.

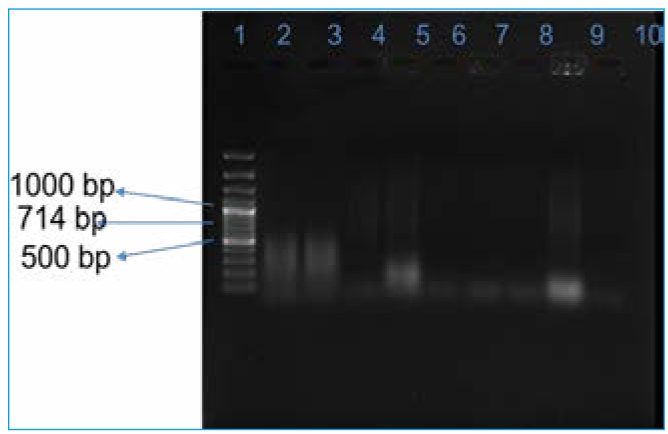


Fig. 18.22. Gel Electrophoresis of PCR products using Tk Primer, shows negative results of the presence of KHV virus. The Marker used is 100 bp DNA step Ladder. Samples are gill, liver, kidney of rohu, mrigal and grass carp Fish from Khagariya

Impact of Combined Application of Organic Manure on Fish Production

To understand the impact of combined application of organic manure, a study was carried out in two identical fish ponds (800 m^2) where in one integration, combination of cattle and goat manure were applied and in other pond, cattle and duck manure were applied. Rohu (*Labeo rohita*) (88.5±5.36g) and Catla (*Catla catla*) (109.7± 5.55g) were reared in those ponds at the rate of 6800 per ha. No external feed was applied. In both the ponds livestock manure was applied on daily basis. Out of 7 month culture period, highest fish production was achieved in cattle + goat combination (2042.49 kg/ha) (Fig. 18.24) similarly highest survivability was also recorded in cattle + goat-fish (95.79%) followed by cattle + duck-fish (76.98%).

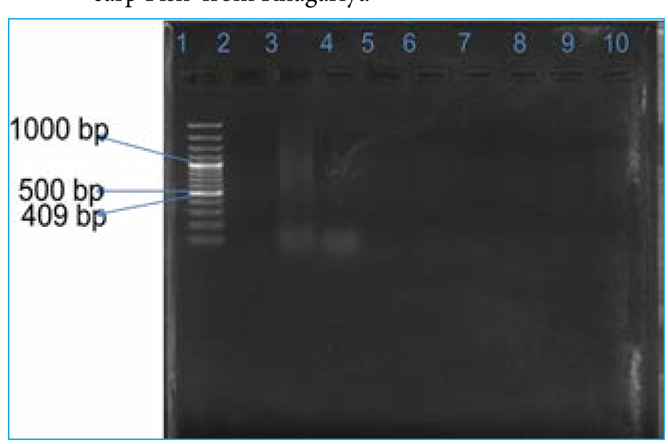


Fig. 18.23. Gel Electrophoresis of PCR products using SVCV. Primer shows negative result of presence of SVCV Virus. The Marker used is 100 bp DNA step Ladder. Samples are gill, liver, kidney of Rohu, Mrigal and grass carp fish from Khagariya

Animal Health Camp

Five animal health camp cum awareness programmes were organized for farmers in two districts of Bihar and Ramgarh district of Jharkhand to educate the farmers about risks of diseases transmitted between animals and human beings (Fig. 18.25). About 220 farmers participated in the awareness programmes. Farmers were told about risks of Bird flu, Brucellosis, Glanders, Tuberculosis, Rabies, Leptospirosis, Cysticercosis etc. The mode of spread and methods of prevention of these diseases was also discussed with the farmers. About 560 animals were dewormed and vaccinated against FMD, HS and BQ.

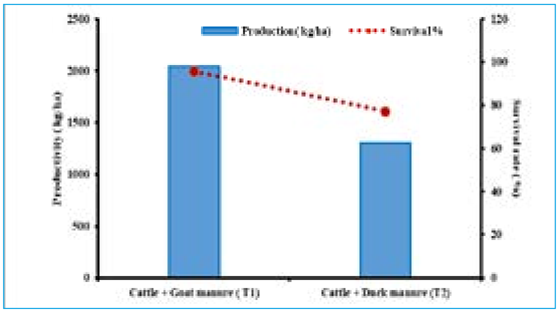


Fig. 18.24. Fish production under different integrated farming system

Assessment of Fish Diversity and Production Potential in Lentic Inland Ecosystems of North Bihar

Phytoplankton diversity and abundance of selected lentic ecosystem of North Bihar

Phytoplankton specimen were collected from the *chaurs* (low land/depressed area) and *mauns* (oxbow lake) of districts of Darbhanga, Madhubani, Motihari, and Samstipur during the period from January 2021 to December 2021. It gives information about the phytoplankton biodiversity and their abundance in the lentic ecosystem. The observed phytoplankton structure and diversity comes under the classes, viz. cyanophyceae, chlorophyceae and the bacillariophycea. 15 species of chlorophyceae (green algae), 8 species bacillariophycea and 6 species cyanophyceae of phytoplankton community were recorded and their distribution shown in shade plot. Under the chlorophyceae class, Cosmarium sp. and closterium sp. were recorded at the rate varying between 157-172 unit per liter during the summer month. The bacillariophycea algae recorded throughout the year with the high density of navicula sp. (25-190 unit/l), *Nitzchia sp.* (15-120 unit/l) and *Synedra sp.* (35-121 unit/l) andunder the cyanophyceae class, nostoc sp. (23-150 unit/l), spirulina (24-250 unit/l), oscillatoria (15-190 unit/l) etc. were recorded throughout the year. However, bacillariophycea and cyanophyceae algal biodiversity were recorded of less density during the winter, which may be due to less dissolved nutrient availability and temperature.

Assessment of fish production potential in Makhana–periphytons system in North Bihar

Growth of periphyton on different substrate

The experiment was conducted to study periphyton growth on the selected substrates at the research field of RCM Darbhanga. Bamboo structure, knitted fabric net (HDPE), and tree branches were used as a substrate for the growth of periphytons in the experimental ponds. Periphyton layers on the substrates surface were used to assess periphyton density (cell/cm^2) and biomass (mg/cm^2) for each substrate. The periphyton density from the bamboo structure was found comparatively higher (26,110±2910 cell/cm^2) than the fabric net (20,179±2105 cell/cm^2). Moreover, the periphyton biomass from the bamboo structure was relatively higher (2.789±0.519 mg/cm^2) than fabric net (1.858±0.321 mg/cm^2).


Fig. 18.25: Animal health camp and awareness programme conducted in villages

19. Socio-economic Studies and Transfer of Technology

Climate Resilient Agriculture Programme (CRAP)

ICAR-RCER, Patna is implementing Climate Resilient Agriculture Programme funded by Government of Bihar under the umbrella programme 'Jal Jeevan Hariyali' in Gaya and Buxar districts through respective KVKs. Major objectives are to develop climate resilient and futuristic cropping system (crop-cycle) modules for different districts and increase awareness among farming community about climate smart technologies through on farm demonstrations. Five villages have been adopted in each district i.e Rasalpur Manpur, Rasalpur Nagar, Rupaspur, Takeya and Rahimbigha in Gaya and Harikisanpur, Dalsagar, Churamanpur, Ramobariya and Balapur in Buxar. Along with demonstration at selected farmers field, long term experiments are being conducted at KVK farms of these districts.

During the year, a total of 1169 ha area was covered in both the districts, out of which 582 ha was in Gaya and 587 ha was in Buxar. The details are given in (Table 19.1).

Table 19.1. Area coverage and beneficiaries under CRA Programme

Seasons	Area covered (ha)			No of beneficiaries		
	Gaya	Buxar	Total	Gaya	Buxar	Total
Summer-2021	100	100	200	253	282	535
Kharif-2021	232.8	238	470.8	640	653	1293
Rabi-2021	249.2	249.2	498.4	652	759	1411
Total	**582**	**587.2**	**1169.2**	**1545**	**1694**	**3239**

Demonstration of climate resilient interventions in Gaya and Buxar during *rabi* 2020-21

Under this programme, demonstration of zero tillage cultivation of wheat (var. HD-2967 and Sabour Shrestha), lentil (var.HUL-57), chickpea (var. Pusa-3043, RVG 202 and Pusa-3043) and mustard (var. RH-749) were laid out at both the districts. Comparative economics of demonstration plots and local check has been presented in (Table 19.2 & 19.3). It was observed that grain yield and straw yield of wheat, lentil, chickpea and mustard were comparatively higher under zero tillage over conventional cultivation in both the districts The grain yield under zero tillage technology increased by 13.6%, 20.7%, 27.6% and 14.7% for wheat, chickpea, lentil and mustard, respectively over local check in Gaya. Similarly, in Buxar district, increase in grain yield was 13.9%, 8.9%, 4.7% and 18.5% in wheat, chickpea, lentil and mustard, respectively.

The profitability was also estimated and it was found that intervention of zero tillage method increased the net returns of wheat, chickpea, lentil and mustard by 32.5%, 85.9%, 64.8% and 131.9% in Gaya and 19.4%, 22.9%, 5.8% and 29.7% in Buxar, respectively. Likewise, benefit:cost ratio was also observed higher in all the crops in both the districts. Intervention of green seeker based nutrient management in wheat also showed promising results at both the locations.

Performance evaluation of zero tillage green gram during summer 2021

During summer, green gram (var. Samrat and IPM-2-3) was demonstrated in selected farmers' field through zero tillage method. Quality seed and other inputs were provided to 535 farmers along with technical support. Zero tillage intervention recorded 0.81 and 0.89 t/ha grain yield at Buxar and Gaya, respectively (Table 19.4) which were 17.4% and 12.6% higher over local check. Zero tillage mungbean gave net returns of Rs. 39287 and Rs. 46244 per ha in Buxar and Gaya, respectively. Mungbean was also used as green manures by some farmers by incorporating it with soil during tender stage.

Demonstration of climate resilient interventions during *Kharif* 2021

During *kharif* 2021, heavy rainfall during the sowing time badly affected the progress of Direct Seeded Rice technology at both the districts. However, transplanting method and drum seeder was used for paddy and a total of 470.8 ha area was covered under cultivation. Quality seeds of rice (var. Swarna Shreya, Swarna Samridhi, Sabour Ardhajal, Rajendra Sheweta, Hybrid- 6444, Swarna Shakti, BPT-5204 and CO-52), maize (var.NHM-803), pearl millet (var.Ankur-45), pigeon pea (var.IPA-

Table 19.2. Evaluation of climate resilient interventions in Gaya during *rabi* 2020-21

Crop	Technology	Grain yield (t/ha)		Straw yield (t/ha)		Net Returns* (INR/ha)		B : C Ratio	
		Demo	Local check	Demo	Local check	Demo	Local check	Demo	Local check
Wheat	Zero tillage	4.67	4.11	5.78	5.47	45,723	34500	2.7	2.3
Chickpea	Zero tillage	1.75	1.45	2.26	1.54	45,100	24250	3.7	2.6
Lentil	Zero tillage	1.48	1.16	2.29	2.09	35,610	21600	3.5	2.5
Mustard	Zero tillage	1.64	1.43	3.74	3.16	45,345	19550	3.9	3.1
Wheat	Green seeker based nutrient management	4.46	4.24	5.64	5.73	46,140	33200	2.7	2.2

***Net returns was estimated on the basis of MSP of the given crops**

Table 19.3. Evaluation of climate resilient interventions in Buxar during *rabi* 2020-21

Crop	Technology	Grain yield (t/ha)		Straw yield (t/ha)		Net Returns (INR/ha)		B : C Ratio	
		Demo	Local check	Demo	Local check	Demo	Local check	Demo	Local check
Wheat	Zero Tillage	4.82	4.23	6.50	6.10	84595	70842.5	3.8	3.2
Chickpea	Seed Drill	1.67	1.53	2.93	2.80	58722	47777.5	3.03	2.59
Lentil	Zero Tillage	1.22	1.17	1.80	1.72	33500	31640	2.2	2.16
Mustard	Zero Tillage	1.15	0.97	3.44	3.23	36887.5	28422.5	2.60	2.13

203) and ragi (var.RAU-8); herbicides and necessary technical guidance were provided for demonstration purpose.

The interventions implemented in rice were direct seeding, transplanting with climate resilient varieties, alternate wetting and drying method of irrigation. Raised bed maize and pearl millet were also demonstrated. Direct seeded rice was found to have slightly higher grain and straw productivity over transplanted one. Among the all rice interventions in both the districts, direct seeded rice showed the highest grain yield (5.52 t/ha) in Buxar. Raised bed planting of maize recorded harvest of 4.85 t/ha and 3.83 t/ha grain yield in Gaya and Buxar, respectively, which were 2.5% and 4.8% higher over conventional technique. Out of all rice varieties (Fig. 19.1), Arize-6444-Gold produced highest grain yield (7.6 t/ha) in Gaya followed by BPT 5204 (7.02 t/ha)in Buxar. Raised bed planting of pearl millet achieved a mean yield of 2.72 t/ha, which was higher than traditional cultivation (2.51 t/ha) at selected villages of Buxar district. All the interventions were found to have a higher net return over conventional farming in all *kharif* crops.

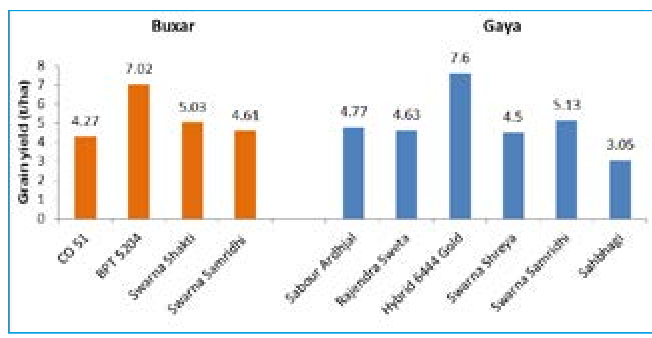


Fig. 19.1. Performance of rice varieties under CRAP at KVK farms at Buxar and Gaya

Estimation of System Productivity in Climate Resilient Production System

System productivity of different cropping systems at Gaya KVK farm is shown in (Fig. 19.2). Among different

Table 19.4. Performance of zero tillage green gram in Buxar and Gaya

Crop	Technology	District	Grain yield (t/ha)		Straw yield (t/ha)		Net Returns (INR/ha)		B : C Ratio	
			Demo	Local check	Demo	Local check	Demo	Local check	Demo	Local check
Mung	Zero tillage	Buxar	0.810	0.69	1.02	0.95	39287	31652	3.05	2.75
		Gaya	0.89	0.79	2.18	2.17	46244	37748	3.6	3.0

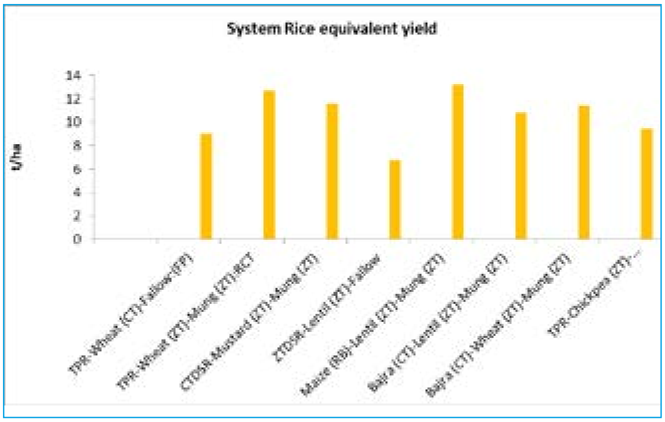


Fig. 19.2. System rice equivalent of different interventions at KVK, Gaya farm

cropping systems, maize-lentil-mungbean was found to have the highest system productivity i.e. 13.2 t/ha, followed by transplanted rice-wheat-mungbean (12.7 t/ha) and direct seeded rice-mustard-mungbean (11.6 t/ha). The *Kharif* maize showed highest rice equivalent yield i.e. 6.08 t/ha, irrespective of crops and seasons.

Capacity Development Programmes

Capacity building activities like training, field days, exposure visits, meeting etc. were also conducted in adopted villages of Gaya and Buxar for the beneficiary farmers. A total of 113 such programmes were conducted this year. Nearly 6000 farmers participated in these events, comprising 80% male and 20% female. It helped them to update their knowledge about climate resilient technologies. A custom hiring center was developed at KVK Buxar (Fig. 19.3), which covered service area of 119.5 ha covering 107 farmers and Rs. 1.78 lakhs revenue was also generated through the Custom Hiring Centre.

Progress of *rabi* crops during 2021-22

A total of 1243 acres area covered under this programme during *rabi* 2021-22. A no. of interventions like zero tillage cultivation of wheat, lentil, chickpea and mustard; raised bed planting of wheat, maize and potato; intercropping of maize with potato; and nutrient expert based nutrient management in wheat were carried out in farmers' fields. High quality seeds of wheat (var. HD-2967 and DBW-187), lentil (var. HUL-57 and IPL-316), chickpea (BG-3043, RVG-202 and GNG-1144), mustard (Pusa mustard-31), potato (var. Kufri Mohan) and maize (var. DKC-9887) were distributed among the growers of selected villages.

Transfer and Adoption of Improved Agricultural Technologies

To identify technology transfer mechanism and constraints to technology transfer, data from 110 officials and scientists of Bihar and Jharkhand were collected. Most of the officials (75 %) were block level extension functionaries (Assistant Technology Manager, Block Technology Manager, *Kisan Salahkar*, etc) and rests were Subject Matter Specialists and scientists. Personal contacts remained the preferred method of technology dissemination used by 70.9% of extension personnel. Trainings, demonstrations, use of social media and exposure visits were also other methods of effective transfer of technologies used by majority of officials of Bihar. Now-a-days there is a frequent and regular monitoring of government funded schemes and activities for the effective implementation of any programme and its desired impact on the farming community. Critical analysis of the data revealed that most of the officials (50.90%) monitored by field visits followed by weekly or monthly meetings either in physical or virtual mode (29.01%). Video calling and social media (12.72%) were also used for onsite monitoring, particularly during the Covid pandemic (Fig.19.4). Monitoring through social media and IT tools had been proven to be an efficient and effective tool for activity monitoring.

Fig. 19.3. Custom hiring center at KVK, Buxar

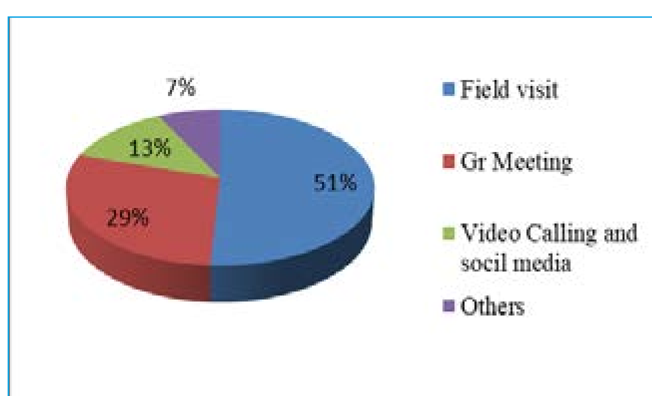


Fig. 19.4. Monitoring of extension personnel

Growth and Instability in Production of Principal Crops in Eastern India

The project was started with the objective to study the growth and instability in production of principal food grain crops in eastern India. In order to study the performance of principal crops in Chhattisgarh and Eastern UP, secondary data since year 2000 on area, production and yield of principal crops were collected and analyzed. From the analysis of data of Chhattisgarh, it was observed that cropping intensity increased from 112 to 121% during last 20 years. A declining trend in foodgrains area had been observed during the period. Decline in area of principal crops was only due to increase in area under other crops. However, the stability (1.19<CV< 1.87) in foodgrains area was observed during last 20 years. Productivity of rice and maize increased significantly during the period.

Analyzing the data of Eastern UP, it was observed that cropping intensity increased from 154 to 167% during last 20 years. It may be due to good practices of farming system in Eastern UP. Eastern UP seemed to achieve stability in rice area (1.79<CV< 4.45). Also, productivity of wheat increased at faster pace than rice and maize during the period.

Status of Utilization of Digital Tools in Agriculture Sector in Eastern India

Under the project, a questionnaire was developed and online survey was conducted among farming community in two states i.e., Bihar and Jharkhand. Buxar district from Bihar and Ramgarh from Jharkhand were selected for the survey regarding importance of digital tools and major problems encountered by the farmers in its use. Results showed that modal age of respondent farmers in Buxar was 50 while in Ramgarh younger farmers were in majority with modal age of 35. The farmers of Buxar were more qualified since majority were graduate while in Ramgarh mostly farmers passed higher secondary education. Use of digital tools was studied in terms of frequency i.e daily, weekly, monthly and occasionally. Majority of respondents in both Buxar and Ramgarh district were observed to use the smart devices including smartphones, laptop, tablet etc. most frequently, i.e., on daily basis to the tune of 64-68%, mainly because of multiple features and easy to handle. The primary mobile phones with only calling facility were used by very less number of farmers in both the districts. However, small phone possession was high (25.4%) in Ramgarh as compared to Buxar (12.4%). This implies that socio-economic condition of farmers from Buxar was better than Ramgarh district.

Production and Value Chain Analysis of Makhana

Under the project, effect of branding on makhana value chain was assessed by analysis of data collected from online resources and telephonic survey. Major industry players of the country involved in branding of makhana were also identified.

Branding in makhana

In case of makhana, branding is done at traders' level or at makhana industries. It is done through value addition by change in form and through certification (Food Safety and Standards Authority of India i.e FSSAI). It is also done by standard packaging which involves design of packet, logo of the company, packaging material used, size of packet etc. There are several industries involved in branding of makhana by adding different flavours viz. chilli, pudina, cheese etc. Shakti Sudha, Makhana Wala, Amrit, Rajbhog, AK Gold, Mr Makhana, Sattviko Neha, Banty aur Babli etc are some popular makhana brands prevalent in the market.

Effect of branding on value chain

Among different firms, prices of 250 g makhana pop was compared and it was observed that there was an increase in price of popped makhana in the range of 53-105% over loose makhana pop. The retail price of loose makhana was taken at Rs 700/ per kg. Mr Makhana, a brand of recently launched company Rishab Global Industries Pvt ltd, New Delhi fixed price of 250g pop at Rs 360 which is 105.7% higher than loose pop in retail market.

Similarly, effect of different quality of makhana on price was also studied for the same firm. In case of Shakti Sudha brand, three types of makhana packets were found namely Classic, Gold and Platinum based on size of pop. The prices of these varied from Rs 925 for classic to Rs 975 for gold and Rs 1150 for platinum packets per kg. Increase in price of Shakti Sudha brand over loose pop ranged from 32-64%. Similar kind of results were also observed for Mithila makhana. Effect of packaging was also studied for different brands. It was observed that zipped polythene pack, plastic jar, normal polythene pack etc were used which had different price in the market. Premium makhana were sold in very attractive packets and had higher prices over normal packets.

Status of Food And Nutritional Security of Farm Households in Eastern India

In this project data from different age groups of children were taken based on WHO Child Growth

Standards. Data were collected from Lodhipur, Bodhibigha of Nalanda district; Karai, Rahgunathpur Bhelura from Patna in Bihar and Dewagain, Kerkata of Namkum district of Jharkhand. Nutritional data were collected based on personal observation and measurements by following 24 hours recall method (Table 19.5).

The results showed BMI of all the 53 children of different age groups was in between 5th to 84th percentile which indicates the children were healthy. In case of 10-12 years girls the value was on lower side of healthiness. It indicates prevalence of less nutrition to this group.

Table 19.5. Nutritional status of children based on age groups

Group	Sample size	BMI	Calories (kcal/d)	Protein (g/day)	Fat (g/day)
Children (4-6 years)	7	14.78 ± 1.07	1298.42 ± 73.63	20.16 ± 0.82	19.92 ± 2.09
Children (7-9 years)	11	15.07 ± 1.49	1695.72 ± 101.99	24.84 ± 1.82	23.90 ±1.57
Boys (10-12 years)	6	18.01 ± 1.48	2382.83 ± 299.04	34.84 ± 2.21	25.16 ±1.94
Girls (10-12 years)	4	14.91 ± 0.71	1943.01 ± 67.95	29.4 ± 0.77	24.5 ±0.58
Boys (13-15 years)	6	15.92 ± 1.79	2607.50 ± 296.17	30.28 ± 3.80	25.33 ± 1.51
Girls (13-15 years)	8	15.27 ± 0.83	2299.875 ± 77.21	44.50 ± 3.60	33.87 ±1.64
Boys (16-17 years)	7	20.86± 1.94	2725.00± 176.98	37.71 ±2.47	34.71 ±1.88
Girls (16-17 years)	4	18.07± 0.59	2356.75 ± 152.41	42.59 ±0.48	34.0 ±2.31

It is also reflected by their protein intake data (29.4 ± 0.77 g/d), lesser than the other groups. Protein intake for almost all the age groups was found lesser than recommended dietary allowance.

It is also revealed from the study that the households having income more than 8000 were spending Rs. 6718.0 towards food in addition to the farm produce worth Rs. 3547.02 (Table 19.6). The middle income group spent Rs. 3064.70 and 4535.12 from their own and farm produce, respectively. The lower income groups spent much less on food i.e., Rs. 1797.00 while majority of their food were consumed from farm (worth Rs. 5986.35) produce. The lower income groups were mainly the wage earners who earned wage and share of farm produce as remuneration.

Development and Validation of Need Based Technology Delivery Model Through Farmers' Producer Organization for Eastern Region of India

Need based technology delivery models developed

The project is intended to develop and validate technology delivery through FPO focused in eastern region of India. The four different models of technology delivery through FPO has been developed for seed production, vegetable production, organic farming and natural resource management in ICAR-RCER, Patna, ICAR-IIVR, Varanasi, ICAR-RCER, FSRCHPR, Ranchi and UBKV, Cooch Behar, respectively depicted in Model 1 to 4 in (Fig.19.5).

Registration of FPOs under the project

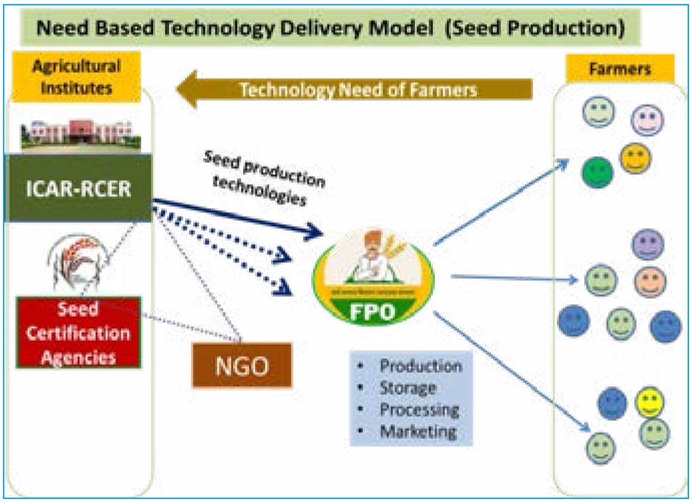
In this project 4 FPCs have been registerd one in Jharkhand, one in Uttar Pradesh and two in West Bengal. The details of FPO is given in (Table 19.7).

Factors determining the progressiveness of farmers in FPO

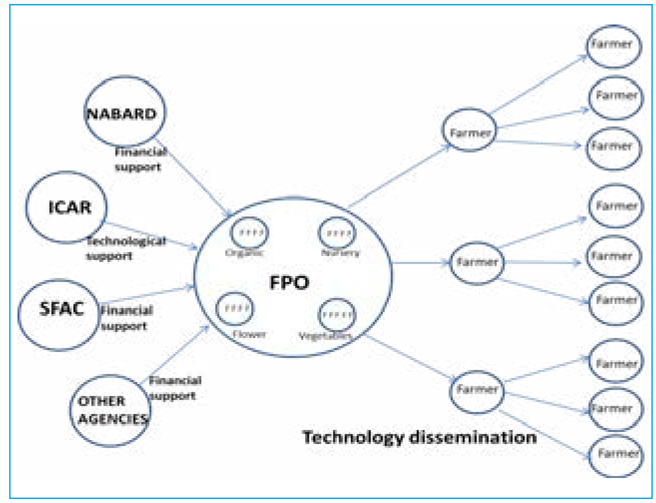
Further the farmers data were used for determining important factor for progressiveness of FPO farmers. Application of Machine learning Random Forest Classification was done with 478 data set in which 306 were used for training, 77 for validation and 95 for testing (Table 19.8). The validation accuracy was found 0.961 and test accuracy was 0.947. Determination, problem-solving, self control, continuous learning and profit orientation were found important variable responsible for progressiveness of FPO farmers in eastern region of India (Table 19.9). E-extension provided to the farmers has also been depicted in (Table 19.10).

Table 19.6. Expenditure (Rs.) of different households and value of farm produce

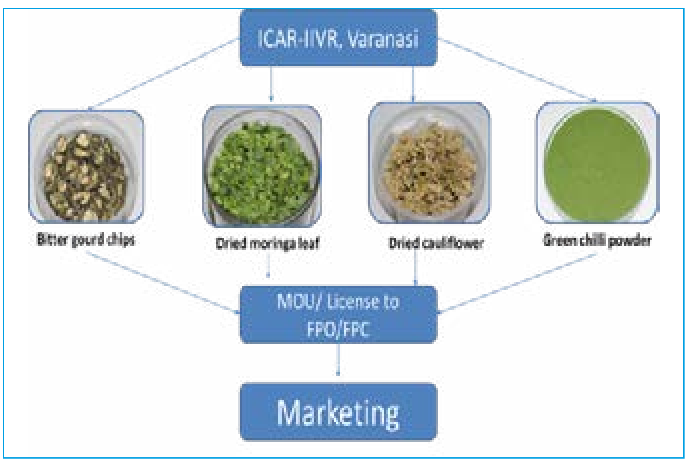
Income group	Monthly income of household	Sample size	Avg. size of each household	Average expenditure on food	Value of Farm produce consumed
Higher income group	More than 8000	n=14	4.273	6718.80	3547.02
Middle income group	5000 to 8000	n=31	4.967	3064.70	4535.12
Lower income group	Less than 5000	n=55	5.673	1797 .00	5986.35



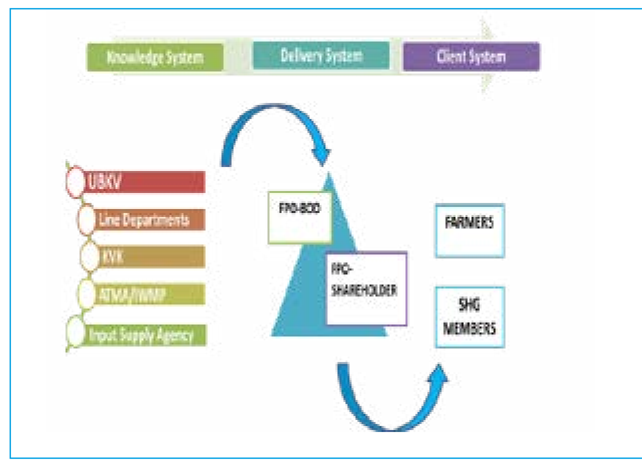
Model 1: FPO based quality seed production and marketing model



Model 2: FPO based safe food production technology delivery model



Model 3: FPO based Vegetable produce marketing technology delivery model



Model 4: FPO based Narural Resource farming technology delivery model

Fig. 19.5. Different technology delivery model develop under NASF

Table 19.7. List of FPOs registerd under the NASF project

S.N.	Name	Registration number
1	Greenery Agrotech Producer Company (FPC) Limited, Jharkhand	U01100JH2020PTC015360
2	Pundibari Krishi Ratna Farmers Producer Company Limited, West Bengal	U01100WB2020PTC241881
3	Thaneswar Farmers Producer Company Limited, West Bengal	U01100WB2020PTC240497
4	Sumrat Bhumi Producer Company Limited, U.P.	U01100UP2021PTC152303

Table 19.8. Random Forest Classification of progressiveness of FPO farmers

Trees	Predictor per split	n (train)	n (validation)	n (test)	Validation accuricy	Test accuracy	OOB accuracy
75	4	306	77	95	0.961	0.947	0.000

Note: The model is optimized with respect to the out-of-bag accuracy.

Table 19.9. Seed distributed/ FLD conducted under NASF Project

S. No.	Crop	Variety	Quantity of seed distributed	No. of farmers adopted	Total FLD area under each variety (ha)
ICAR- RCER-Patna Lead Centre					
1.	Paddy	Swarn Shreya	760 kg	101	45.41
		Swarn Sambridhi	200 kg	26	12.5
		Swarn Sakti	200 kg	24	11.66
2.	Wheat	HD-2967	100 kg	23	9.58
3.	Green gram	IPM 2-3	375 kg	161	24.58
ICAR- RCER- FSRCHPR, Plandu, Ranchi Centre					
1	Grafted tomato	Swarn Baibhav	3000 plants	10	0.2
2	Lablab bean	HADB-32	20 kg	22	1
3	Pointed gourd	Swarn Alaukik & Swarn Suruchi	3000 plants	7	0.2
4	Water melon	Sweet king	2.8 kg	20	4
5	Paddy	Swarn Shreya	60 kg	10	1
ICAR- IIVR, Varanasi Center					
1	Cowpea	Kashi Nidhi	20.00 kg	30	1.00
2	Okra	Kashi Kranti & Kashi Lalima	10.00 kg	27	0.50
3	Bottle gourd	Narendra Rashmi	5.00 kg	43	1.00
4	Sponge gourd	Kashi Rakshita	5.00 kg	50	1.00
5	Ridge gourd	Kashi Khushi	5.00 kg	45	1.00
6	Pumpkin	Kashi Harit	5.00 kg	57	2.50
7	Brinjal	Kashi Sandesh	1.00 kg	12	3.33
8	Chilli	Kashi Ratna & Kashi Abha	1.5 kg	14	4.16
9	Tomato	Kashi Aman	1.080 kg	13	2.70
10	Pea	Kashi Uday	250.00 kg	7	1.56
11	Capsicum	Swarn Atulya & Huntington(Hyb)	50.00 gm	2	1000 sqm
12	Mushroom spawn	Oyster	100.00 kg	20	5 mushroom unit

UBKV, Cooch Behar, West Bengal Centre			
Sl. No.	**FLD technologies**	**Project beneficiary through FPO**	**Technology out scaled to beneficiaries**
1.	Zero tillage Jute and modern cultivation of Jute	4	122
2.	Zero tillage mustard	5	65
3.	Mushroom cultivation and processing	6	52
4.	Mulching in vegetables and garlic	21	158
5.	Tomato post harvesting and processing	9	22

Table 19.10. e-extension service provided under NASF FPO Project

Sl.No	Centre	No. of WhatsApp group	Number of users
1	ICAR- RCER-Patna	2	156
2.	ICAR- RCER- FSRCHPR, Plandu, Ranchi	1	126
3.	ICAR- IIVR, Varanasi	-	-
4.	UBKV, Cooch Behar, West Bengal	9	558

Resource Inventorization of Flood plain Wetlands in Eastern India

Under this project, the study was undertaken in two selected wetlands Kamla Balan and Bagmati river catchment area in Bihar. The village Babu Barahi of Babu Barahi block in Madhubani district and Ladaur village of Gayaghat block in Muzaffarpur district adjoining Kamla Balan and Bagmati river catchment area, respectively were selected for the study. A total of 170 household comprising 100 from Babu Barahi and 70 from Ladaur village was interviewed. Flood frequently comes during July to September month. The range of flood water depth was in between 1 to 2.5 meter and duration of water stagnation was in between 12 to 21 days in general. The kachha and pakka houses in the village was in the ratio of 7:3. The health status of majority of the respondents was observed to be good (70%) followed by very good (15%), and poor (15%). Around 70% individuals' occupation was agriculture while 15% were daily wage labours and another 15% were government employees. As many as 15% individuals were attached to NGO or KVK or in contact with agriculture coordinators in the block. Study revealed that major fruit crops of the area were mango, banana, litchi, jackfruit, guava, custard apple, blackberry, lemon and main vegetables are potato, chili, pumpkin, lady finger, brinjal, cucumber, bittergourd and pointed gourd in this region. Rice was the staple crop during *kharif* season and mostly rice based cropping systems were followed like rice-wheat, rice-potato, rice-lentil, rice-moong, rice-maize, rice-wheat-moong, rice-potato-moong, rice-lentil-moong and rice-maize-moong. The maximum and minimum cropping system productivity was observed in case of rice-potato-moong (18.22 t/ha) and rice-moong (8.25 t/ha), respectively. The major fish species were catla (*Catla catla*), rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*), cyprinus (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*) and big head (*Hypophthalmichthys nobilis*) and around 20% individuals were involved in fisheries activities.

The productivity of aquaculture was around 1.2 ± 0.86 t/ha. Around 35% individuals reared cow and the dominant cow breeds were Sahiwal, Holstein Friesians crossbreed and indigenous breed. Nearly 45% populations reared buffalo and Murrah was the major buffalo breed while 22% individuals reared goat and major breed were Bengal goat and Jamunapari in these wetlands.

Area covered and family income from agricultural resources like food grains, aquaculture, vegetable and fruit were also presented in (Fig. 19.6 and Fig. 19.7). The average food grain production area in the flood plain wet land was found to be 0.74 acre in which maximum acreage was 3.5 acre and minimum 0.1 acre. The average aquaculture area was 0.38 acre in which maximum area was 0.75 acre and minimum 0.2 acre. The average vegetable area was 0.31 acre in which maximum area was 1.5 acre and minimum 0.1 acre. The average fruit area was 0.56 acre in which maximum area was 1.5 acre and minimum 0.1 acre. There was significant ($p<0.05$) difference between acreage of agricultural resources except food grains with vegetable and aquaculture. There was significant ($p<0.05$) difference between income of all resources. Maximum income was gained through aquaculture followed by vegetable, fruit and food grain.

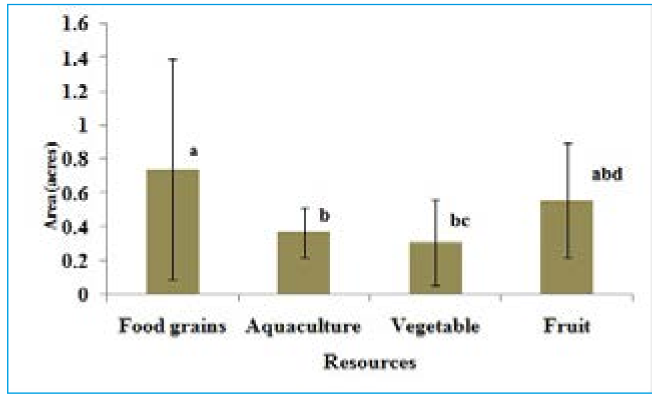


Fig. 19.6. Annual income per family from agricultural resources

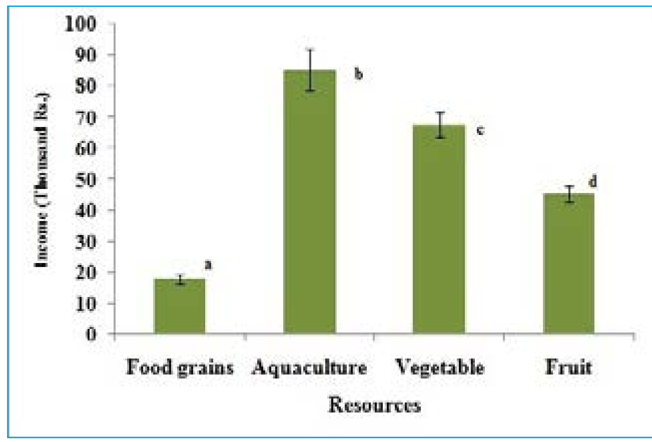


Fig. 19.7. Area covered per family by agricultural resources

Model Based Inference on Agricultural Crops for Food Security in Eastern India

The study was initiated with the objectives to study the trend, impact of climatic parameters and forecast the production of principal crops in eastern India. Secondary time series data on rice production (thousand tones) of eastern India for the period from 2001 to 2017 were collected. Structural time series data (STSM) model has been used and data for the period from 2001 to 2014 were used for model development and data for the period from 2015 to 2017 for validation of the model. The trend analysis of rice production in eastern India revealed that the rice production might increase in the upcoming years till 2024 in eastern India (Fig. 19.8). The AIC values for the structural time series model was 245.33. The model was validated with the actual three years rice production data from 2015 to 2017 and observed that the model predicted the rice production within 10 % error (Table 19.11).

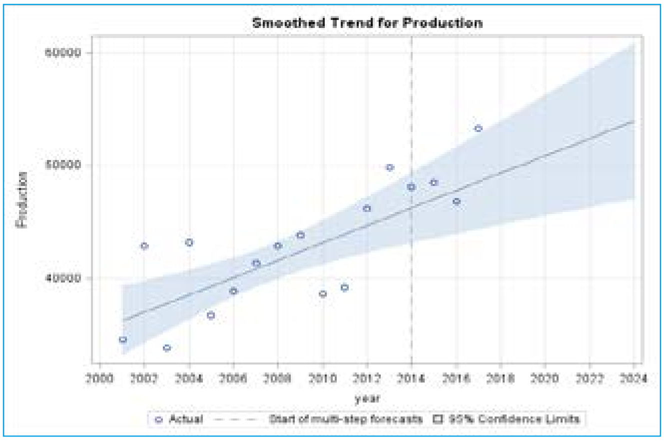


Fig. 19.8. Rice production trend increasing till 2024 in eastern region, India observed by structural time series modelling

Table 19.11. Actual, forecasted and absolute percentage error in rice production of eastern India using STSM model

Year	Actual	Forecast	Absolute % prediction Error
2015	48497.58	46046.44	5.05
2016	46803.59	45922.04	1.88
2017	53299.15	48086.18	9.78

Socio-Economic Characterization of Farmers in Bihar and Jharkhand

M-K-J-B-D (Maheshwari-Kumar-Jhamtani-Bhaskaran-Dandapani) multidimensional scaling method was used to construct the socio economic status (SES) scale for farmers of Bihar and Jharkhand. Data were collected from 492 farmers during 2021 from Jehanabad, Kaimur, Jamui, Seikhpura, Nawada and Rohtas districts of Bihar and Bokaro, East Singhbhum and Ramgarh districts of Jharkhand. Factor analysis was applied to the data obtained for identification of factors (indicators), variables (sub-indicators) and their weightage in the socio-economic status scale.

Ten components (factors) could explain a total variance up to 93 per cent (Table 19.12). After restricting the number of components to ten, factor analysis was again employed to obtain the beta values for each variable. The variables which have major contribution to a particular component have higher beta values than for other components.

On the basis of beta values of variables to a particular component, the components are given a name to represent the group of variables. Since these components are uncorrelated, there is no covariance and hence no overlapping scores. Now, these components could be used to obtain scores of individual respondents. Mathematically it could be represented as Total Multidimensional Score (Y) = $Y_1 + Y_2 + Y_3 + Y_{4+} \dots\dots\dots Y_{10.}$ Based on factors and formula for component score, socio economic status scale for farmers of Bihar and Jharkhand was developed which contains 10 factors and 19 variables (Table 19.13).

Reliability test of this scale was assessed using Split half method. Correlation coefficient was found to be 0.96 and reliability coefficient 0.97. Thus scale is reliable. Further, this scale will be subjected to validity test.

Socio-Personal Profile of Farmer Respondents

Socio-personal profile of 492 farmers from Bihar and Jharkhand is given in Table 3. Forty seven percent farmer respondents were OBC followed by 29 % general, 20 % SC, 2% ST and rest 2% belonged to other castes in Bihar. However, 56% farmer respondents were ST followed by 34% SC, 8% OBC, 0.32% general and rest 1.28% other castes in Jharkhand. In both states of Bihar and Jharkhand, nuclear family dominated. Only one-third of the total families were joint family type in both states. About 96% farmer respondents were literate in Bihar. However, only 79% farmers were literate in Jharkhand. About 97% farmers respondents were found in healthy condition in Bihar and only 81% farmers in Jharkhand were healthy. Regarding knowledge of PM Jan Arogya Yojana, 88 % farmers were having knowledge in Bihar but only 45% farmers in Jharkhand were having

Table 19.12. Eigen values of the Reduced Correlation Matrix

S. No.	Eigen value	Difference	Proportion	Cumulative
1	6.10	3.73	0.31	0.31
2	2.37	0.40	0.12	0.43
3	1.97	0.20	0.10	0.53
4	1.78	0.36	0.09	0.61
5	1.42	0.30	0.07	0.69
6	1.13	0.10	0.06	0.74
7	1.12	0.07	0.05	0.80
8	1.09	0.09	0.05	0.84
9	1.03	0.08	0.04	0.89
10	1.01	0.09	0.04	0.93
11	0.69	0.03	0.03	

Table 19.13. Socio-economic status scale for farmers

S. No.	Factors (Items)	Variables (sub-items)			
1	Income	Cultivable land- 0.92	Total land- 0.85	Irrigated land- 0.82	Total family income- 0.49
2	Housing	Type of house- 0.64	Type of roof- 0.61		
3	Health & hygiene	Healthy - 0.48	Use of gas cylinder - 0.46		
4	Personal behaviour	Invitation in social activities- 0.63	Leadership- 0.48		
5	Social contact	Contact with Agriculture coordinator- 0.76	Contact with Veterinary doctor- 0.72	Contact with MLA/ MP- 0.73	
6	Occupation	Occupation of family members- 0.48			
7	Animal wealth	No. of Buffalo- 0.51			
8	Education	Smart phone- 0.54	Classes passed- 0.47		
9	Organizational membership	Membership in the organization - 0.51			
10	Women participation	Women participation in agriculture- 0.51			

knowledge of this scheme. About 44% farmers were having *kuchcha* house followed by 32% *pucca* and 24% mixed houses in Bihar. In Jharkhand, 74% farmers were having *kuchcha* house followed by 16% mixed and 10% *pucca* houses. A total of 82% farmers in Bihar were having toilet facilities in their houses while 52% farmers of Jharkhand were having toilet facilities (Table 19.14).

Enhancing Food, nutritional and livelihood Security of Marginal and Small Farmers in Jharkhand through Need Based Agricultural Technologies (Farmer FIRST Project)

The project is being implemented to demonstrate need based technologies for ensuring livelihood security of small and marginal farmers. During the year 2021, a total of 795 numbers of technology demonstrations were undertaken covering total area of 20.48 ha and 522 numbers of animals in four villages of Khijri block of Ranchi (Table 19.15 & Fig. 19.9). The activities under the project resulted in additional income of Rs 35.34 lakh in the villages.

Table 19.14. Socio-personal profile of respondents

Socio-personal variables	Category	Frequency (%)	
		Bihar (N= 178)	Jharkhand (N= 314)
Caste	General	52 (29)	1 (0.32)
	OBC	83 (47)	25 (8)
	SC	36 (20)	107 (34)
	ST	3 (2)	177 (56)
	Others	4 (2)	4 (1.28)
Family type	Nuclear	131 (74)	221 (70)
	Joint	47 (26)	93 (30)
Education	Illiterate	7 (4)	67 (21)
	Literate	171(96)	247 (79)
Health status	Healthy	173 (97)	255 (81)
	Not healthy	5 (3)	59 (19)
PM Jan Arogya Yojana	Having knowledge	157 (88)	140 (45)
	Having no knowledge	21 (12)	174 (55)
Type of house	Kuchcha	78 (44)	232 (74)
	Mixed	42 (24)	51 (16)
	Pucca	58 (32)	31 (10)
Toilet facility	Yes	145 (82)	162 (52)
	No	32 (18)	152 (48)

Expansion of Activities of Biotech KISAN Hub in Seven Aspirational Districts in Jharkhand and Bihar (DBT funded)

The project is being implemented in collaboration with KAUSHALYA Foundation, Patna to scale up the production of high value horticultural crops and to establish value chain linkages in East Singhbhum, Khunti, Ramgarh, Bokaro districts of Jharkhand and Nawada, Sheikhpura and Jamui districts in Bihar. During 2021-22, technology demonstrations (2052 numbers) on cultivation of high value horticultural crops viz, sweet corn, broccoli, strawberry, carrot, capsicum, mushroom, papaya were undertaken in a total area of 44.04 ha in farmers' fields in 14 villages in seven aspirational districts.

The cropwise economic benefits accrued to the farmers due to the technology demonstrations are given in (Table 19.16). The maximum net profit was recorded in strawberry cultivation (Rs 12.89 lakh per ha) followed by off season cultivation of cauliflower. The B:C ratio of different crops ranged between 1.48 (capsicum) to sweet corn (4.34).

The level of adoption of different technologies varied among the different districts which is given in (Table 19.17). Among all the technologies demonstrated, cultivation of broccoli, sweet corn, strawberry and oyster mushroom were either fully adopted or In the process of

Table 19.15. Details of demonstrations undertaken in Jharkhand during 2021

Name of crop	No. of demonstration	Area (ha)	Yield (q/ha)		Net income (Rs/ha)	
			Farmers practice	Field demonstration	Farmers practice	Field demonstration
Crop diversification in rainfed uplands through moong variety IPM -2-3	48	2.4	7.26	9.6	24300	32100
Crop diversification in rainfed uplands through DSR variety Sahbhagi	61	3.07	10.02	22.5	13026	26000
Rainy season cultivation of tomato variety Swarna Sampada	87	4.3	109.42	198.11	164100	247000
Cultivation of leguminous vegetables (French bean variety HAFB 7)	103	0.86	13.46 (Upland paddy)	114.6 (Rice equivalant yield 131.53)	13460	114600
Cultivation of bitter gourd variety Swarna Yamini	52	0.32	131.23	158.41	262000	316820
Cultivation of sponge gourd variety Swarna Prabha	67	1.12	205.72	272.32	308000	408000
Cultivation of potato variety Kufri Kanchan	126	1.01	83	136	90000	160000
Cultivation of wheat variety DBW 187 in Rice fallow	97	4.87	13.40 (paddy)	System productivity: REY 42.02 (Paddy-14.14q/ha+ wheat-19.33 q/ha)	13500	54000
Cultivation of bottle gourd variety Swarna Sneha in rice fallow	57	0.28	13.40 (paddy)	System productivity: REY 196.90 (Paddy-14.21q/ha+ bottle gourd-168.40 q/ha)	13500	243940
Feed supplement of animals with Area specific mineral mixture	60	142 cows, 236 goat, 144 pig	Cow: 1.9 litres per day, Goat: Mean daily body wt. gain 56.62 g	Cow: 2.4 litres per day, Goat: Mean daily body wt. gain 88.12 g	Cow: Rs 9500/- per lactation per animal , Goat: Rs 10800/- per animal	Cow: Rs 13900/- per lactation per animal , Goat: Rs 16200/- per animal
Integrated farming system (Field crops+ Vegetables+ Dairy+ Goat+ Poultry+ Mushroom)	6	2.18	REY: 76.26	REY: 152.08	148000	295000
Cultivation of oyster mushroom	31	5600 kg substrate	-	Biological efficiency: 76.8%		11100 (per unit)

Direct Seeded rice variety Shahabhagi in rainfed uplands

Oyster mushroom cultivation

Fig. 19.9. Field demonstration of technologies

Table 19.16. Crop wise economic benefits accrued to farmers due to technology demonstration

Crops	Production (t)	Productivity (t/ha) (% biological efficiency in mushroom)	Total value of produce (Rs in lakh)	Net profit per ha (Rs in lakh) (Rs per kg substrate in oyster mushroom)	Net profit of farmer (Rs in lakh)	B:C ratio
Broccoli	205.49	36.15	33.74	4.51	24.85	3.62
Sweet corn	86.38	13.25	19.69	2.59	14.36	4.34
Pencil bean	74.76	13.96	16.20	2.41	10.76	3.23
Carrot	38.31	17.66	8.40	2.95	6.41	4.24
Strawberry	2.08	6.07	6.81	12.89	3.92	2.52
Oyster mushroom	9.86	1.42	12.57	134.04	9.37	3.68
Rainy season tomato	180.88	19.01	23.12	2.12	16.30	3.71
Capsicum	1.60	3.45	0.82	0.63	0.25	1.48
Early cauliflower	53.38	34.99	10.15	5.62	8.53	6.54

Table 19.17. Level of adoption of different technologies in farmers' fields

Name of the interventions/ technology transferred	Districts in which fully adopted	Change in income	
		Before	After
Broccoli (variety Fiesta)	Khunti, East Singhbhum, Bokaro, Nawada	Rs 3.28 lakh per ha from main season cauliflower	Rs 4.51 lakh per ha
Sweet corn (variety Sugar 65)	Bokaro, Ramgarh Khunti,	Rs 0.86 lakh per ha from Maize	Rs 2.59 lakh per ha
Pencil bean (variety HAFB 37)	Ramgarh, Khunti, Jamui	Rs 1.62 lak per ha from Bush type French bean	Rs 2.40 lakh per ha
Carrot (variety Pusa Kesar)	Bokaro	Rs 2.68 lakh per ha in carrot variety Clause	Rs 2.94 lakh per ha
Strawberry (variety Winter Down)	Jamui	Rs 0.46 lakh per ha from cultivation of vegetables	Rs 12.88 lakh per ha
Capsicum (Swarna Atulya)		Rs 0.46 lakh per ha from cultivation of vegetables	Rs 0.63 lakh per ha
Mushroom cultivation	East Singhbhum, Jamui, Nawada, Sheikhpura	Rs 10.0 per kg of paddy straw	Rs 134.0 per kg of substrate used

adoption in all the districts except in Jamui. In contrast, the technology on Fertigation in vegetables was not adopted in any of the districts except Khunti and Sheikhpura.

For establishment of value chain of the above mentioned horticultural crops, 41 Farmers' groups with 492 members, 14 numbers of WhatsApp groups with 564 farmer members have been formed and 15 numbers of Agri-Enterpreneurs have been identified for marketing of the produce. Apart from this, two number of Farmer Producer Companies (FPO) have also been registered involving participating farmers under the project from Khunti and Ramgarh districts of Jharkhand for the purpose of strengthening value chain of the high value horticultural crops. The name of the FPCs are;

1. Khunti- Krishak Producer Company Limited, Khunti, Jharkhand
2. Ramgarh Kisan Producer Company Limited, Ramgarh, Jharkhand

The activities under the project resulted in total production of 680.52 tonnes of high value horticultural crops with a gross value of Rs 135.23 lakh. The total profit earned by the farmers due to the technology demonstrations made under the project was Rs 94.56 lakh (Table 19.18). Maximum net profit (Rs 20.59 lakh) was earned by the farmers in Ramgarh district of Jharkhand. During the year under report, technology demonstration under the project resulted in 7.19% increase in the total annual agricultural income of the farmers in the adopted villages (Fig. 19.10).

Table 19.18. District wise economic benefits accrued to the farmers under the project

District	Number of demonstrations	Area (ha) or quantity of mushroom substrate (kg)	Total production of high value horticultural crops (t)	Gross value of produce (Rs in lakh)	Net profit earned by the farmers under the project (Rs in lakh)
Khunti	315	16.18	106.55	25.13	13.87
Ramgarh	308	11.40	230.36	30.44	20.59
Bokaro	284	3.70	103.06	18.53	14.14
East Singhbhum	146	4.19	36.70	10.86	7.00
Nawada	214	2.12	44.06	13.22	10.59
Jamui	339	3.01	87.20	18.90	14.28
Sheikhpura	446	3.44	72.59	18.16	14.10
Total	**2052**	**44.04**	**680.52**	**135.23**	**94.56**

Broccoli in farmers' fields in Khunti district of Jharkhand

Technology demonstration on strawberry cultivation in Jamui district of Bihar

Fig. 19.10. Views of demonstrations in farmers' fields

Frontline Demonstrations (FLDs) of Rice Varieties

The frontline Demonstrations (FLDs) of rice varieties Swarna Shreya, Swarna Shakti Dhan and Swarna Samriddhi Dhan were conducted by ICAR-RCER, Patna during *kharif* 2021 at 127 beneficiary farmers' (including 25 women farmers) fields covering an area of 44.8 hectares in five districts (Nawada, Gaya, Jamui, East Champaran and Buxar) of Bihar and Ramgarh district of Jharkhand (Fig. 19.11). The performance of the demonstrated rice varieties (Swarna Shreya, Swarna Shakti Dhan and Swarna Samriddhi Dhan) were found superior compared to the respective check varieties. Rice variety Swarna Shreya recorded an average of 4.15 t/ha recorded yield advantage of 13.5% over check variety and was found suitable for increasing the rice productivity and production in the demonstrated districts. Moreover, Swarna Shakti Dhan recorded an average grain yield of 4.24 t/ha and showed 14.8% yield advantage over check varieties. In addition, Swarna Samriddhi Dhan recorded average grain yield of 4.93 t/ha and showed 18.01% yield advantage over check variety. Farmers of the demonstrating villages were very happy and satisfied with the performance of these climate resilient rice varieties.

Organization of Field Days under FLDs Programme

Field days were organized by ICAR RCER, Patna at Chiraya block (East Champaran), Rupaspur in Gaya

Fig. 19.11. Breeder seed production of rice varieties

district, Mahulidih village in Nawada, Harikishunpur in Buxar and Sonpai in Jamui of Bihar on 08th, 22nd, 23rd, 29th and 30th October 2021, respectively with the objective to see the performance of newly released climate resilient rice varieties Swarna Shreya, Swarna Shakti Dhan and Swarna Samriddhi Dhan at farmer's field grown under frontline demonstration (FLDs) programme. Besides, Field days were also organized at Barmasi and Badka Chumba villages, Ramgarh (Jharkhand) on 21st and 23rd October 2021 respectively to observe the performance of newly released drought tolerant aerobic rice varieties Swarna Shakti Dhan and Swarna Shreya. More than 400 farmers, scientific staff of KVK and scientists of ICAR RCER participated in the field day progarmmes. All participants visited the demonstration plots and shared their experiences during field days. Farmers were very happy and excited over the performance of climate resilient rice varieties Swarna Shreya, Swarna Shakti Dhan and Swarna Samriddhi Dhan.

Breeder Seed Production of Rice Varieties

Breeder seeds of rice varieties Swarna Shreya (38.6 q), Swarna Shakti Dhan (24.9 q) and Swarna Samriddhi Dhan (35.4 q) were produced by ICAR RCER, Patna during kharif 2021. The representatives of National Seed Corporation (NSC), Patna, Bihar Rajya Beej Nigam, State Seed and Organic Certification Agency (BSSOCA), Patna and scientific staff of ICAR RCER, Patna participated in monitoring of breeder seed production of these rice varieties (Fig. 5.7). Besides, nucleus seeds (2.75 q) of rice varieties Swarna Shreya, Swarna Shakti Dhan and Swarna Samriddhi Dhan were also produced during kharif 2021. Moreover, truthfully labeled (TL) seed of rice varieties Swarna Shreya (31 q), Swarna Shakti Dhan (17 q) and Swarna Samriddhi Dhan (24 q) were also produced during Kharif 2021.

Seed Distribution of Rice Varieties

The seed of Swarna Shreya, Swarna Shakti Dhan and Swarna Samriddhi Dhan were distributed on foundation day of ICAR RCER, Patna to more than 150 farmers belonging to different districts of Bihar for on-farm testing during *kharif* 2021. Seeds of these rice varieties were also distributed to more than 125 farmers belonging to Ramgarh district of Jharkhand and Jamui, Buxar, Gaya, East Champaran and Nawada districts of Bihar for frontline demonstrations (FLDs) during *kharif* 2021.

Agri-Business Incubators Centre

During the year 2022, a total of three numbers of entrepreneurs were registered as Incubatees the details of which are given in (Table 19.19).

Table 19.19. Details of incubatees registered under the ABI project

Name of technology	Name of Incubatee	Date of signing of MoA
Button mushroom production	Mr. Bineet Singh, Ranchi	22/01/2021
ITK based ayurvedic medicinal formulation	Mrs. Albina Ekka, Namkum, Ranchi	27/01/2022
Button mushroom production	Mrs. Bandana Ranjan, Jamshedpur	04/02/2022

Activities under SCSP

Agricultural inputs were distributed among 50 farmers of Kunda block, Chatra district, Jharkhand under SCSP (Table 19.20). Field demonstration, training etc. were also undertaken under the programme.

Table 19.20. Distribution of agricultural inputs among SC farmers

Indicators	Achievement	No of Beneficiaries
Training/ Demons-trations/ Field days/ Exposure Visits	Training: 19 nos. Demonstrations: 15 nos. Field days: 07 nos. Exposure visits: 03 nos.	952
Equipment provided to farmers	Re-chargeable torch: 25 nos. Tarpolin: 250 nos. HDPE crate: 1500 nos. Knapsack sprayer: 435 nos. Seed storage bin: 277 nos. Water pump: 170 nos. Grain storage bin: 517 nos. Sickle: 100 nos. Water cane: 500 nos. Garden rake: 500 nos.	3297
Distribution of Inputs (vegetable/ pulse/ maize/ rice/ seed) Pesticides	Trichoderma: 180 kg Vermi-compost: 8540 kg Dolomite: 1500 kg Tomato seed: 18 kg Garden pea seed: 100 kg French bean seed: 150 kg	1074

Indicators	Achievement	No of Beneficiaries
Distribution of Inputs (vegetable/ pulse/ maize/ rice/ seed) Pesticides	Chickpea: 300 kg Cowpea seed: 90 kg Dolichos bean seed: 75 kg Pole bean seed: 350 kg Satputia seed: 30 kg Lentil: 100 kg Mustard: 35 kg Protray: 500 nos. Vegetable seeds: 100 kg Mineral Mixer: 5000 kg	
Distribution of Saplings	Point guard: 3500 nos. Papaya: 1000 nos. Drum stick: 250 nos	55
	Total	**5320**

Plant Variety Registration

Plant Variety registration certificate received for ridge gourd variety Swarna Sawani from PPV&FRA, New Delhi (REG/2019/135)

Commercialization of Technology

MoU

- MOU was signed with M/s Maitri Enterprises, Ranchi on 23.09.2021 for Hybrid Seed production of tomato indeterminate hybrid SWARNA ANMOL, released by ICAR RCER FSRCHPR, Ranchi.
- MoU was signed by M/s Maitri Enterprises, Ranchi for large scale seed production of open pollinated varieties and lines of 21 vegetable crops developed by the Centre and Mother block establishment of pointed gourd varieties Swarna Rekha, Swarna Alaukikand Swarna Suruchi on 23.09.2021.

MTA

- MTA was signed with Professor, College of Horticulture,Anatarajupeta, Dr YSR Horticultural University for ten brinjal varieties, one capsicum variety and one soyabean variety on 4.10.2021
- MTA was signed with Kousthubha V. P. MSc Scholar, Dept. of Vegetable Science, College of Agriculture, Vellanikera, Kerala Agricultural University for sponge gourd variety Swarna Prabha on 2.2.2022

Linkages

Besides having linkages with leading ICAR institutions, SAUs and State Govt. of various eastern states, the details of other linkages is depicted below:

International Collaborations

Research areas	Collaborating institutes
Conservation Agriculture	CIMMYT
Climate resilient cropping systems	CIMMYT
Improving water use for dry season agriculture	CIMMYT
Sustainable and resilient farming system intensification for EIGP	CIMMYT
Development of submergence tolerance rice varieties for flood plain and flood prone areas of eastern region	IRRI
Development of drought tolerance rice varieties for eastern region	IRRI
Restoration of degraded lands, water congested areas and carbon sequestration	World Agroforestry Centre
Developing suitable pulse varieties of lentil, grass pea and pigeonpeafor drought tolerance in eastern states	ICARDA
Small ruminants improvement and production system	ILRI

Other Collaborations

Research areas	Collaborating institutes/ Regional Centres
Integrated Farming System	IVRI RC, Kolkata; IISWC RC, Koraput; IARI RS, Pusa (Bihar); CIFRI; CPRS RS, Patna, IIFSR, Modipuram, MGIFRI, Motihari and NBSS&LUP
Tribal Farming System	IISWC RC, Koraput, Odisha, and NBSS&LUP
Quality brood management, fish seed, enclosure culture and wetland rehabilitation	CIFA; CIFRI; CRRI; NRC (Pig); AAU and CTCRI
Livestock & Avian Production System	IVRI; NRC (Pig); NDRI; AAU; UBKV; BAU (Bihar); BAU (Ranchi) and CARI
Seed production of agri-horti crops including production technology	DSR, Mau; IARI RS, Pusa; BISA (CIMMYT) Pusa; CRRI; BAU (Bihar & Ranchi); RAU, Pusa; IIVR; CTCRI; CHES; NRC, Litchi; CSISA; DMR; CPRS-RS, Patna & UBKV.

20. Trainings and Capacity Building

Following employees of the Institute have undergone training during 2021

Table 20.1. List of employees undergone training

Category	Total No. of employees	No. of trainings planned for each category during 2021-22 as per ATP	Total No. of employees undergone training during January to December 2021	% Realization of trainings planned during 2021-22
Scientist	71	12	20	100.00
Technical	46	3	7	100.00
Administrative & Finance	17	16	3	18.75
SSS	36	10	0	0
Total	170	41	19	73.17

Feedback of trainees were collected, consolidated and sent to ICAR, New Delhi.

HRD fund allocation and utilization (Rs. in Lakh)

S. No.	BE 2021-22 for HRD	Actual expenditure up to December, 2020	% Utilization
1	0.56	0.56	100.00

Sponsored Training Programmes

- Training programme on 'Mushroom cultivation' during 5th to 15th January, 2021 sponsored by NGO-Going to School.
- Training programme on 'Vermicomposting' during 2nd to 12th February, 2021, Patna sponsored by NGO-Going to School.
- Training programme on 'Recent advances in composite fish culture practices' sponsored by Koshi Basin Development Program, Govt of Bihar during 3rd to 5th February, 2021.
- Training programme on 'Integrated farming system' during 8th to 18th February, 2021 sponsored by NGO-Going to School.
- Training programme on 'Recent advances in composite fish culture practices' sponsored by Koshi Basin Development Program, Govt of Bihar during 18th to 20th February, 2021.
- Training programme on 'High value crop cultivation practices in Jharkhand and Bihar districts' sponsored by Department of Biotechnology, Govt. of India, organized at ICAR RCER, FSRCHPR, Ranchi during 25th to 27th February, 2021.
- Training programme on 'Mushroom spawn and cultivation techniques' sponsored under ICAR-NASF project organized at ICAR RCER, FSRCHPR, Ranchi during 1st to 3rd March, 2021.
- Training programme on 'Scientific vegetable cultivations' sponsored by Amal Manav Jagrati Kalyan Sansthan, Kaimur (Bihar) organized at ICAR RCER FSRCHPR, Ranchi during 4th to 6th March, 2021.
- Training programme on 'Improved techniques of mushroom cultivation' sponsored by ICAR-DMR, Solan organized at ICAR RCER FSRCHPR, Ranchi during 8th to 10th March, 2021.
- Training programme on "On-farm water management strategies for enhancing land and water productivity" sponsored by ATMA, Gopalganj at ICAR-RCER, Patna from 08-13th March, 2021.
- Training programme on 'Improved techniques of mushroom cultivation' sponsored by ICAR-DMR, Solan organized at ICAR RCER FSRCHPR, Ranchi during 11th to 13th March, 2021.
- Training programme on 'High value crop cultivation practices in Jharkhand and Bihar districts' sponsored by Department of Biotechnology, Govt. of India, organized at ICAR RCER, FSRCHPR, Ranchi during 15th to 17th March, 2021.

- Training programme on 'Agri entrepreneurship opportunities in Jharkhand' sponsored under ABI project organized at ICAR RCER FSRCHPR, Ranchi during 18th to 20th March, 2021.
- Training programme on 'Climate resilient fruits and vegetables cultivation in Bihar' sponsored by ATMA, Jehanabad, Bihar organized at ICAR RCER FSRCHPR, Ranchi during 22nd to 26th March, 2021.
- Training programme on "Popularization of Resource conservation through precision farming technologies" under CRP on Farm Mechanization & Precision Farming project at ICAR-RCER, Patna from 23rd to 25th March, 2021.
- Training programme on 'Small interventions in agricultural practices for doubling income' sponsored by Schedule Caste Sub Plan (SCSP) at ICAR-RCER, Patna during 28th to 30rd July, 2021. About 210 participating farmers attended the training programme.
- Online training on 'Climate smart technologies for improving farm productivity' sponsored by MANAGE (Hyderabad), was organized during 14th to 17th September, 2021.
- Training programme on 'Recent advances in Composite fish culture practices' sponsored by Koshi Basin Development Program, Govt of Bihar during 30th November to 4th December, 2021.

Training Programme Conducted

- Training on 'Climate smart technologies for natural resource management' during 28th to 30th January, 2021.
- Training programme on 'Scientific practices in seed production and marketing' under NASF Project organized during 2nd to 4th March, 2021.
- Training programme on 'On-farm water management strategies for enhancing land and water productivity' from 8th to 13th March, 2021.
- Training on 'Climate smart technologies for improving farmers' income' during 16th to 18th March, 2021.
- Training programme on '*Kukkut paalan se aajivika sudhar*' at ICAR-MGFRI, Motihari from 21st to 24th March, 2021.
- Training programme on 'Poultery production' during 22nd to 24th March, 2021 at ICAR-MGIFRI, Motihari.
- Online training programme on 'Nursery raising and cultivation of papaya' on 10th July, 2021.
- Demonstration cum training programme on 'Small interventions in agricultural practices for doubling income' during 28th to 30th July, 2021.
- Demonstration cum training programme on 'Small interventions in agricultural practices for doubling income' during 2nd to 4th August, 2021.
- Training programme on 'Repair, maintenance & operation of power tiller' from 2nd to 4th August, 2021 at KVK, Ramgarh, Jharkhand
- Demonstration cum training programme on 'Small interventions in agricultural practices for doubling income' during 5th to 7th August, 2021.
- Training programme on 'Repair, maintenance & operation of power tiller' from 5th to 7th August,2021 at KVK, Ramgarh, Jharkhand
- Training programme on 'Repair, maintenance & operation of tractor' during 11th to 13th August, 2021 at KVK, Buxar,Bihar
- Training programme on 'Repair, maintenance & operation of tractor' from 17th to 19th August, 2021 at KVK, Buxar, Bihar
- Online training programme on 'Climate smart technologies for improving farm productivity' during 14th to 17th September, 2021.
- Training programme on 'Repair, maintenance & operation of power tiller' from 20th to 22nd September, 2021 at KVK, Ramgarh, Jharkhand
- Training programme on 'Repair, maintenance & operation of power tiller' during 23rd to 25th September, 2021, KVK, Ramgarh, Jharkhand
- Training programme on 'Repair, maintenance & operation of tractor' from 23rd to 25th September, 2021 at KVK, Buxar, Bihar
- Training programme on 'Repair, maintenance & operation of tractor' during 28th to 30th September, 2021at KVK, Buxar, Bihar
- Training programme on 'Equipment for paddy harvesting, wheat sowing and crop water management for small land holders' from 8th to 10th December, 2021at KVK, Ramgarh
- Training programme on 'Agronomic management of *rabi* crops with special reference to farming system approach' during 22nd to 25th December, 2021.

Field Day/Kisan Goshthi/Mass awareness programme

- Post flood management strategies on 30th January, 2021 at Ladaur village, Muzaffarpur.
- Animal health camp organized during 10th to 11th February, 2021 at Chintamanpur village of Chakiya block of East Champaran district of Bihar.
- Pashu Aarogya Mela organized during 18th to 19th February, 2021 at KVK, Piprakothi, Motihari.
- Post flood management strategies on 23rd February, 2021 at Nima Belam village, Rahika, Madhubani district .
- Field day on Application of precision farming technology in increasing farm productivity on 5th August, 2021, Budhakhap village, Ramgarh, Jharkhand.
- Field day on Application of precision farming technology in increasing farm productivity on 6th August, 2021, Jobla village, Ramgarh. Jharkhand.
- Field day on Scale up of horticulture production under micro-irrigation system on 16th September, 2021at Kashibigha and Teus villages of Sheikhpura district.
- Post flood management strategies on 20th September, 2021 at ICAR RCER RCM Darbhanga.
- Field day on Application of precision farming technology in increasing farm productivity on 24th September, 2021, Badgaon village, Mandu block Ramgarh. Jharkhand.
- Agricultural resources management in floodprone areas on 16th October, 2021 at Ladaur village, Muzaffarpur.
- Post flood management strategies towards enhancing agricultural productivity on 1st December, 2021 at Ladaur village, Muzaffarpur.
- Field day on 'Line sowing of wheat through Raised Bed Planter' on 02nd December, 2021 at Ramobariya village, Block & District, Buxar.
- Field day on 'Line sowing of wheat through happy seeder' on 3rd December, 2021 at Harikishunpur Village, Block & district Buxar.
- Field day on 'Line sowing of wheat through seed cum fertilizer drill on 4th December, 2021 at Balapur Village, Block & district Buxar.
- Field day programme on Operation, repair and maintenance of irrigation equipment on 7th December, 2021at Nad Village, Sirdala Block, Nawada.
- Field day on Sowing of wheat/ Chick pea/ Lentil through Zero tillage technique on 15th December, 2021 at Harikishunpur village in Buxar District.
- Field day on Sowing of wheat/ Chick pea/ Lentil through Zero tillage technique on 18th December, 2021 at KVK, Buxar.
- Field day on Sowing of wheat/ Chick pea/ Lentil through Zero tillage technique on 19th December, 2021 at Athar village, Nawanagar block in Buxar District.
- Field day on Sowing of wheat/ Chick pea/ Lentil through Zero tillage technique on 22nd Decembe,r 2021 at KVK, Buxar .
- Field day on Sowing of wheat/ Chick pea/ Lentil through Zero tillage technique on 24th December, 2021 at Churamanpur, Buxar District.
- Field day on Sowing of wheat/ Chick pea/ Lentil through Zero tillage technique on 31st December, 2021 at Pawani village, Chausa block, Buxar District.

Trainings Attended by the Employees during 2021

- Akram Ahmed, scientist. Online training programme on "Application of IOT in Agriculture" during 6-10th July 2021 at Gandhi Institute for Technology (GIFT) Bhubaneswar.
- Akram Ahmed, scientist. Online training Program on "Enhancing Agricultural Resilience through Index-based Flood Insurance and Post-flood Management Interventions in India" organized by ICAR-IIWM & IWMI Collaboratively during 29-30th June 2021.
- Akram Ahmed, scientist. Online training programme on 'GIS & Remote Sensing" during 4-8th January 2021at University College of Engineering, JNTU Kakinada
- Arti Kumari, Scientist. Online training program on "Geospatial Modelling for Watershed Management" during 02-06th August 2021 organized by IIRS, Dehradun.
- Arti Kumari, Scientist. Online training program on "Geospatial technology for hydrological modelling" during 19-30th July 2021 organized by IIRS, Dehradun.
- Arti Kumari, Scientist; Ashutosh Upadhyaya, Principal Scientist. 2021. Online training program

on "Watershed Hydrological Modelling" during May 17th - June 6th 2021, organized by the Centre for Advanced Agricultural Science and Technology (CAAST) on Climate-Smart Agriculture and Water Management (CSAWM) under the World Bank aided National Agricultural Higher Education Programme (NAHEP) of the Indian Council of Agricultural Research (ICAR), New Delhi.

- Pankaj Kumar, Sr. Scientist. MDP on Leadership Development (a Pre-RMP Programme) from 14 to 25 June 2021, conducted by ICAR-NAARM, Hyderabad.
- Pankaj Kumar, Sr. Scientist. Training Program for Technical Committee member, 17-18 Feb, 2021, Conducted by National Institute of training for Standardization, BIS, Noida as Sectional Committee member.
- R.S. Pan Online Training Programme on "Entrepreneurship Development through Hi-tech Horticulture" organized by Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal on 06-07 August, 2021
- R.S. Pan Online Training Programme on "Strategies for attracting and retaining youth in Agriculture" organized by Bankers Institute of Rural Development (BIRD), Lucknow, U.P. on 09-10 November, 2021.
- Saurabh Kumar, Scientist. DST Sponsored training on "Genome Data Analysis" organized by VIT-TBI on 31 July, 2021.
- Saurabh Kumar, Scientist. Online International multidisciplinary faculty development programme on "Applications of Genomics, Metagenomics and Bioinformatics in Biological Systems" organised by Sri Aurobindo College, University of Delhi & ICMR AIIMS Computational Genomics Centre in collaboration with Mahatma Hansraj Faculty Development Centre Hansraj College, University of Delhi during 16-20 August, 2021.
- Saurabh Kumar, Scientist. Online training program on "Transcriptomic Data Analysis" organized by Centre for Agricultural Bioinformatics, ICAR - Indian Agricultural Statistics Research Institute, New Delhi during 28-30 September, 2021.
- Saurabh Kumar, Scientists. Training course on "Next Generation Sequencing Bioinformatics" organized by H3ABioNet/Welcome Connecting Science.
- Shanker Dayal, Pr. Scientist. Training programme for nominees of CPCSEA organized by CPCSEA, New Delhi from 15-16, June, 2021.
- Shanker Dayal, Pr. Scientist. Training programme on DNP data analysis for detection of parentage in animals" organized by GADVASU, Ludhiana on 23 September, 2021.
- Sonaka Ghosh, Scientist. Professional Attachment Training (PAT) at Indian Institute of Remote Sensing, ISRO, Dehradun, Uttarakhand during 1 March, 2021 – 31 May, 2021.
- Upadhyaya A, Principal Scientist and Rahman A, Pr. Scientist. Online training program on "Modelling Soil Physical Processes for Improving Resource Use Efficiency in Agriculture" on 08 December 2021 organised by Indian Society of Agrophysics and Division of Agricultural Physics, ICAR- Indian Agricultural Research Institute, New Delhi.
- Ved Prakash, Scientist. Online training program on "Advances in web and mobile application development" organized by ICAR-NAARM, Hyderabad during 06th-10th December, 2021.
- Ved Prakash, Scientist. Online training program on "Geo-informatics in agriculture, using open-source data and analysis platforms" at Division of Agriculture physics, IARI, New Delhi during 01-05 March, 2021.
- Ved Prakash, Scientist. Online training program on "Strategies for climate risk management and resilient farming" organized by CRIDA in collaboration with MANAGE, Hyderabad during 20-24 September, 2021.

Participation in Conferences/Seminars/Workshops/Symposia/Meetings

Ahmed Akram and Manibhuhan. 2021. National Webinar on "Crop Diversification: A way towards Nutritional Security"organized by the ICAR-Research Complex for Eastern Region, Patna, Bihar from October 5-7, 2021.

Ahmed Akram, Kumari Arti, Manibhushan and Prakash Ved. 2021. National Conference on "Integrated Farming Systems: A Tool for Enhancing Income and Nutritional Security" organized by the ICAR-Research Complex for Eastern Region, Patna, Bihar from October 5-7, 2021.

Bharti Vivekanand. 2021. National Webinar on "*Disease and Health Management in Aquaculture & Cuture of Marine Fish Sea Bass*" organized by Marsco Aqua Clinics-AquaOne Centre on 5th July 2021.

Bharti Vivekanand. 2021. **N**ational Webinar "*Scientific Goat Farming : From the Livelihood to Financial*

Security for the Farmers" organized by the ICAR-RCER, Patna, Bihar 18th September, 2021.

Bharti Vivekanand. 2021. **N**ational webinar on "*A composite farming: a way for rural livelihood*" at ICAR-RCER, Patna on 29th June, 2021.

Bharti Vivekanand. 2021. **N**ational webinar on "*Casting into future of Fisheries and Aquaculture*" organized by School of Fisheries, Centurion University of Technology and Management (CUTM), Odisha on 22nd and 23 June, 2021.

Bharti Vivekanand. 2021. **N**ational Webinar on "*Composting and Vermi-Compost*" organized by ICAR, New Delhi, 16th December, 2016.

Bharti Vivekanand. 2021. **N**ational Webinar on "*Crop Diversification: A way towards Nutritional Security*" which was organized by the ICAR-RCER, Patna, Bihar on 26th October, 2021.

Bharti Vivekanand. 2021. National Webinar on "*Recent Advances in Animal Genetics for Improving Poultry Productivity*", organized by ICAR-RCER, Patna on 28th August, 2021.

Bharti Vivekanand. 2021. Webinar on "*Agricultural Research Management System (ARMS)*" organized by ICAR, New Delhi, on 22nd October, 2021

Bharti Vivekanand. 2021. Webinar the "*National campaign on system diversification in aquaculture*" conducted at ICAR-RCER, Patna on 1st September, 2021.

Choudhary AK. 2021. Brainstorming session on "Climate smart management in rice-based systems of India: key learning, research gaps and way forward for collaborative research" organized jointly by ICAR-IRRI in virtual mode on 27th July, 2021.

Choudhary AK. 2021. Consultation Meeting for Partnership with Research Institutes for achieving India's voluntary targets of land restoration on 12th February, 2021 organized by Ministry of Environment, Forest and Climate Change, Govt of India (*Online mode*).

Choudhary AK. 2021. Group Meet of State Varietal Trials organized (online) on 2nd November, 2021 by BAU, Sabour.

Choudhary AK. 2021. Kharif Pulses Group Meet on 27-28th May, 2021 organized (Online) by IIPR, Kanpur.

Choudhary AK. 2021. Meeting for finalizing the Seed Rolling Plan for Bihar organized (online) by State Agriculture Department, Govt of Bihar on 30th December, 2021.

Choudhary AK. 2021. Review meeting of Pulse Seed Hubs organized (online) by IIPR, Kanpur on 14th October, 2021.

Choudhary AK. 2021. Webinar on "Management of Parthenium" on 16th August, 2021 organized online by DWR, Jabalpur.

Choudhary AK. 2021. Workshop on "Management strategies for tackling flood and drought problems in Bihar" on 28th January, 2021 organized by Indian Institute of Water Management, Bhubneshwar and ICAR RCER, Patna (*Online mode*).

Choudhary AK. 2021. Workshop on "Scaling up biofortification through seed policy reforms" organized (online) by Harvest Plus on 20th July, 2021.

Dayal Shanker. 2021. International Symposium on "Harnessing the potentials of genome editing tools to augment the productivity and health of farm animals organized by Animal Biotechnology Centre of ICAR - National Dairy Research Institute, Karnal from 19-20th July, 2021

Dayal Shanker. 2021. Virtual International conference on " promising genetic and genomic technology-frontier in selection and animal improvement" jointly organized by Vetrinay College and Research Institute Orathanadu, Tamilnadu and College of Veterinary and Animal Science, Pookode, kerala from from 27 – 28th January, 2021.

Jaipal S. 2021. Choudhary. National Seminar on "Horticulture for Next Generation in Eastern India" organized by Bihar Agricultural University, Sabour, (Bhagalpur), Bihar during 05-06th August, 2021.

Jaipal S. 2021. Choudhary. National webinar on "Crop Diversification: A way towards Nutritional Security" on 26th October, 2021.

Jaipal S. 2021. Choudhary. National webinar on "Invasive Pests and Diseases Problem in Indian Agriculture" organized by N. M. College of Agriculture, Navsari Agricultural University, Navsari on 7th August, 2021.

Jaipal S. 2021. Choudhary. National webinar on "Nutritional security in India: Issues and way forward" on dated 04th September, 2021.

Jaipal S. 2021. Choudhary. National web-symposium on "Recent Advances in Beneficial Insects and Natural Resins & Gums" organized by ICAR-IINRG, Ranchi during 25-26 February, 2021.

Jaipal S. 2021. Choudhary. National workshop & stakeholders' meet on "Medicinal plants in Eastern India: Constraints and Prospects" on dated 06th August, 2021.

Jeet P. 2021. National Webinar on "ArcGIS for Real Time Situational Awareness" on 18th August, 2021 organized by Esri India Geovision.

Jeet P. 2021. National Webinar on "Constraints in adoption of farm machines by tribal farmers in Chhotanagpur Plateau" held on 14th January, 2021 at ICAR-RCER, Patna.

Jeet P. 2021. National Webinar on "Model & Analyse Slurry Pipeline Hydraulics" on 27th January, 2021 organized by ImageGrandfix Software.

Jha B.K. 2021. 5th International Agronomy Congress-2021 organized by Indian Society of Agronomy, New Delhi at PJTSAU, Hyderabad during 23-27th November, 2021.

Jha B.K. 2021. 9th Indian Horticulture Congress-2021organized by Indian Academy of Horticulture Sciences, New Del at CSAUAT, Kanpur from 18-21th November, 2021.

Jha B.K. 2021. National Seminar (Hybrid mode) on "Rice -fallow Management in Eastern India" on 26th August, 2021.

Kirti Saurabh. 2021. National webinar on "Nanotechnology in agriculture: opportunities and challenges" organized by national academy of agricultural sciences-Bhopal chapter & ICAR-IISS, Bhopal on 21st June, 2021.

Kirti Saurabh. 2021. Online ICAR-IRRI Brainstorming Session on "Climate Smart Management in rice-based systems of India: Key Learnings, Research Gaps, and Way Forward for Collaborative Research" on 27th July, 2021

Kumar Pankaj. 2021. International Conference. X Asian Buffalo Conference ABC 2021 on Buffalo Production for Food security and livelihood, 25-29th October, 2021. Nepal (Virtual)

Kumar Pankaj. 2021. International Web Conference on Innovative and Current Advances in Agriculture & Allied Sciences (ICAAAS 2021) held July 19-21, 2021, Organised by Society for Scientific Development in Agriculture and Technology, Meerut (U.P.)

Kumar R. 2021. 5th International Indian Society of Agronomy Congress 2020 held at Hyderabad during 23-27 Novmbr, 2021.

Kumar Sanjeev. 2021. AICRP on IFS Biennial Workshop (virtual platform), organized by IIFSR, Modipuram, U.P.

Kumar Sanjeev. 2021. Meeting called for Briefing on Integrated Farming System to PMO, organized by NRM division, ICAR, New Delhi and IIFSR, Modipuram (U.P.)

Kumar Sanjeev. 2021. Meeting called for preparation of work plan for NMSA in Bihar. Organized by Secretary, Agriculture, Govt. of Bihar

Kumar Sanjeev. 2021. Stakeholders Dialogue on Strategies for Safe and Sustainable Weed Management - A Way Forward, organized by TAAS, ICAR, DWR, Jabalpur and ISWS.

Kumar Sanjeev. 2021. Web Conference and represented IFS in Bihar state in the ICAR-IIFSR-DAC interface meeting on IFS for Western Himalaya, MGP, UGP.

Kumar Santosh. 2021. Advanced meeting (AGGRi)-India, organized by IRRI on 16th July 2021 in virtual mode.

Kumar Santosh. 2021. Brainstorming session on "Climate Smart Management in rice-based system of India: Key Learning, Research Gap, and Way Forward for collaborative Research" held on 27th July 2021 in virtual mode.

Kumar Santosh. 2021. Indo-US Online Workshop on "Analysis of Functions Expressed by Microbiomes" funded by American Society of Microbiology (ASM) and Indo-United States Science and Technology Forum (IUSSTF), CSIR-Institute of Microbial Technology (CSIR-IMTECH), Chandigarh, India along with Galaxy-P Team at the University of Minnesota, Minneapolis, USA hosted the workshop from 15th to 24th November 2021.

Kumar Santosh. 2021. International webinar on "Enhancing food and nutritional security through promoting R4D in dryland crops: ICRISAT's role" organized by Bioingene.com on 26 July, 2021.

Kumar Santosh. 2021. International webinar on "Genetic Engineering Approaches to Develop Climate Smart Rice" organized by Bioingene.com on 26 June, 2021.

Kumar Santosh. 2021. International webinar on "Genome editing for improvement of abiotic stress tolerance of rice" organized by Bioingene.com on 6 April, 2021.

Kumar Santosh. 2021. National webinar on "Artificial Intelligence for Smart Agriculture" on 22 July, 2021 organized by ICAR-RCER, Patna, Bihar.

Kumar Santosh. 2021. Seed rolling plan meeting for next three years organized by department of agriculture, Government of Bihar on 19.08.2021 in virtual mode.

Kumar Saurabh. 2021. International Bioinformatics workshop for Cancer Genomics. Organized by Decode Lifesciences during 1-12 March 2021

Kumar Saurabh. 2021. International Bioinformatics workshop on Genome Informatics during 5-21 April, 2021

Kumari Arti. 2021. Global symposium on salt affected soils-GSAS-21 virtually held on 20-22 October, 2021

Kumari Arti. 2021. Webinar on "Cyber space and Cyber Security" on 27th July, 2021 organized by Library Resource Centre, Sushant University, Gurugram.

Makarana G. 2021. International Webinar Conference on "Alternate Cropping Systems for Climate Change and Resource Conservation" from 29th September to 01st October 2021, organized by ICAR-Indian Institute of Farming Systems Research Modipuram, Meerut.

Makarana G. 2021. International Webinar on "Managing Soil for Producing Nutritional Food and Mitigating Climate Change", Friday, 1st January 2021, organized by Department of Agriculture and Environmental Sciences, NIFTEM.

Makarana G. 2021. International Webinar on "Role of legumes and pulses in sustainable cropping system of Hot arid zone" on July, 17th 2021, organized by SKRAU Bikaner.

Makarana G. 2021. National Seminar (hybrid mode) on "Rice fallow management in Eastern India" organized by ICAR Research Complex for Eastern Region, Patna, Bihar on August 26th 2021.

Makarana G. 2021. National webinar on Use of Nanotechnology In Agriculture Nano Fertilizer on 23rd September, 2021 jointly organized by ICAR Research Complex for Eastern Region, Patna Indian Farmers Fertilizer Cooperative Limited, Patna, Bihar.

Makarana G. 2021. Online Collaborative Training Programme on "Climate Smart Technologies for Improving Farm Productivity", organized jointly by the ICAR-Research Complex for Eastern Region, Patna (Bihar)and National Institute of Agricultural Extension Management, Hyderabad (Telangana) during September14th -17th, 2021.

Makarana G. 2021. Webinar on "Agricultural residues conversion to biofuels through solar powered microwave pyrolysis" on 27th August, 2021 organized by ICAR Research Complex for Eastern Region, Patna, Bihar 800014.

Makarana G. 2021. Webinar on "Dairy vyavsay hetu chaare ka utpadan evan sanrakshan" on June, 22nd 2021, organized by ICAR-NDRI, Karnal.

Pan R.S. 2021. National e-Conference on "Integrated Farming Systems: A Tool for Enhancing Income and Nutritional Security" on 5-7 October, 2021.

Pan R.S. 2021. National Webinar on "Crop Diversification: A Way towards Nutritional Security" on 26 October, 2021.

Pan R.S. 2021. Online 2nd International Agro-biodiversity Congress organized at Rome, Italy by the Italian Ministry of Foreign Affairs and the Alliance Biodiversity International and CIAT during 15-18 November, 2021.

Pan R.S. 2021. Online 7th Annual Review Meeting of NASF projects on 6 January, 2021.

Pan R.S. 2021. Online XXXIX Annual Group Meeting of AICRP (Vegetable Crops) organized by ICAR-Indian Institute of Vegetable Research, Varanasi during 7-9 September, 2021.

Pan R.S. 2021. Virtual Awareness Training Programme on "Germplasm Registration on Horticultural Crops" organized by ICAR-Indian Institute of Horticultural Research on 1 October, 2021.

Pan R.S. 2021. Virtual Brainstorming Meeting on "Digital Sequence Information and Germplasm Sharing" organized by NBPGR, New Delhi on 1 March, 2021.

Pan R.S. 2021. Webinar on "Entomophagy for livelihood security and ecological engineering for innovative pest management" on 22 September, 2021.

Pan R.S. 2021. Webinar on "Nutritional Security: Challenges & Opportunities on Gender Sensitive Agriculture" organized by ICAR-Central Institute for Women in Agriculture on 25 March, 2021.

Pan R.S. 2021. Webinar on "Rice-fallow management in Eastern India" on 26 August, 2021.

Prakash V. 2021. Hindi workshop on "Statistical genetics and its application in agriculture" organized by the ICAR-IASRI, Ned Delhi, during March 18-20, 2021.

Prakash V. 2021. International Conference (Virtual) on "Alternate Cropping Systems for Climate Change and Resource Conservation" organized by the ICAR-IIFSR, Modipuram, Meerut from 29th September to 01st October 2021.

Prakash V. 2021. International webinar on "Fighting the hunger suing smart technology" organized by ICAR-Indian Institute of Oil Palm Research, Pedavegi, A.P. on 26th October, 2021

Prakash V. 2021. Online training workshop program on "Analysis of Multi-Location Data" organized by ICAR-NAARM, Hyderabad during 28th October - 1st November, 2021.

Rahman A. 2021. Seminar on Solar Powered Greenhouse and Precision Farming. Organized by Precision Farming Development Centre (PFDC) and College of Agricultural Engineering, RPCAU, Pusa Bihar &NCPAH, MoA & FW, Govt. of India, New Delhi. on 13th January 2021,

Shivani. 2021. Meeting of "Nagar Rajbhasha Karyanvayan Samiti"was Organized by NRAKAS, Patna at Central Revenue Building, Patna on 28th January, 2021.

Shivani. 2021. Workshop on "Rajbhasha adhiniyam 1963, Rajbhasha niyam 1976, masaoda lekhan evm aarakshan roster" organized by ICAR RCER, Patna, Bihar on 12/032021

Singh Jaspreet. 2021. National webinar on "*Casting into the future of Fisheries and Aquaculture*" organized by School of Fisheries, Centurion University of Technology and Management (CUTM), Odisha. 22-23 June, 2021.

Singh Jaspreet. 2021. National webinar on "*Geospatial Approaches for Agricultural Water Management*"organized by Centre of Excellence on Water Management NAHEP, DR. RPCAU Bihar, on 7-9 Oct 2021.

Singh Jaspreet. 2021. National webinar on "*Integrated Farming System for Livelihood and Nutritional Security*"*organised by* National Agricultural Higher Education Project- Centre for Advanced Agricultural Science & Technology, Birsa Agricultural University, Ranchi. (7-8 July 2021).

Singh Jaspreet. 2021. International conference cum exhibition "*Seaweed India, 2021*" on 26-27 August, 2021.

Singh Jaspreet. 2021. International E-workshop on "*Fundamentals of Remote Sensing*" organized by Geo Vigyan on 3-4th July, 2021.

Singh Jaspreet. 2021. National webinar on "*Artificial Intelligence for Smart Agriculture*" organized byICAR RCER, Patna on 22nd July, 2021.

Singh Jaspreet. 2021. National webinar on "*Feed Certification*"Funded by NFDB under PMMSY and organized by TNJFU, Chennai on 14th September, 2021.

Singh Jaspreet. 2021. Virtual symposium on "*The Recent Trends in Aquaculture Industries*" organised by Centre for Ocean Research and Sathyabhama University, 20-25 July, 2021.

Sonaka Ghosh. 2021. Online 5th International Agronomy Congress on "Agri-innovations to combat food and nutrition challenges" held at PJTSAU, Hyderabad, Telangana during 23rd to 27th November, 2021.

Sonaka Ghosh. 2021. Online National Seminar on "Agrophysics for Smart Agriculture" organized by Indian Society of Agrophysics at NASC, New Delhi during 22nd to 23rd February, 2022.

Tripathi M.K. 2021. International symposium on harnessing the potentials of genome editing tools to augment the productivity and health of farm animals Organised at ICAR- National Dairy Research Institute Karnal , July 19-20, 2021

Tripathi M.K. 2021. International Conference. X Asian Buffalo Conference ABC 2021 on Buffalo Production for Food security and livelihood, 25-29 Oct, 2021. Nepal (Virtual)

Tripathi M.K. 2021. International Web Conference on Innovative and Current Advances in Agriculture & Allied Sciences (ICAAAS 2021) held July 19-21, 2021, Organised by Society for Scientific Development in Agriculture and Technology, Meerut

Tripathi M.K. 2021. International workshop on "Scientific writing" Organised at ICAR- National Dairy Research Institute Karnal , June 23-24, 2021

Upadhyaya A, Jeet P, Ahmed A, Sundaram PK, Kumari, A, Manibhushan and Rahman A. 2021. 55th Annual Convention of Indian Society of Agricultural Engineers (ISAE) and International Symposium on "Emerging Trends in Agricultural Engineering Education, Research and Extension" held during 23-25 November, 2021 organized at Patna, Bihar.

Upadhyaya A. 2021. 20th Regional Coordination Committee (RCC) V meeting of the Centre for Flood Management Studies (CFMS), National Institute of Hydrology, Patna on 22nd June, 2021.

Upadhyaya A. 2021. Celebration of Special Day-Kisan Diwas under Swachchata Abhiyan organized by ICAR Research Complex for Eastern Region, Patna on 23rd December, 2021

Upadhyaya A. 2021. Farmers' Awareness Programme on Balanced Use of Fertilizers at ICAR Research Complex for Eastern Region, Pana on June 18th, 2021.

Upadhyaya A. 2021. Lecture on Public-Private Partnerships for sustainable irrigation: Toles of government, users and the private sector delivered by Dr. Steve Goss, Economic Advisor to World Bank, under Azadi Ka Amrut Mahotsav on 7th June, 2021.

Upadhyaya A. 2021. Scientists' Farmers' Interaction Meet on Climate Resilient Agricultural Technologies organized at ICAR Research Complex for Eastern Region, Pana on 28th September, 2021.

Upadhyaya A. 2021. State Level Committee for Assessment of Groundwater Resources of Bihar on 5th April, 2021.

Upadhyaya A. 2021. Task Force Committee Meeting for Middle Gangetic Plains at ICAR Research Complex for Eastern Region, Pana on 17th August, 2021.

Upadhyaya A. 2021. Webinar on Modelling Soil Physical Processes for Improving Resource Efficiency in Agriculture, organized by Indian Society of Agrophysics in Association with Division of Agricultural Physics, ICAR-IARI, New Delhi on 8th December, 2021.

Upadhyaya A. 2021. World Food Day, organized by Bihar State Productivity Council, Patna on 16th October, 2021

Upadhyaya A. 2021. XVII Research Advisory Committee at ICAR Research Complex for Eastern Region, Patna on 2nd February, 2021.

Webinar/Conference/Workshop Organised under Azadi ka Amrit Mahotsav

1. Webinar on "*Tillage Systems and their Effect on Soil Properties*" on 27 January, 2021. About 70 participants attended the webinar
2. National webinar on "*A composite farming: a way for rural livelihood*" on 29 June, 2021. About 100 participants attended the webinar
3. National webinar on "*Ecosystem Management for Sustainable Fisheries*" on 10 July, 2021. 69 nos. of farmers and processors participated in the webinar.
4. Webinar on "*Artificial Intelligence (AI) for Smart Agriculture*" on 22 July, 2021. About 300 participants attended the webinar.
5. Webinar on "*Applications of Remote Sensing in Precision Agriculture*" on 28 July, 2021. Around 200 participants registered for the webinar from all part of the country.
6. Webinar on "Ecosystem for Sustainable FPOs" on 30 July, 2021. Around 270 participants registered for the webinar from all part of the country.
7. Webinar on "*Krishi me jal sanrakshan va saksham jal upyog ki taknitain*" on 31 July, 2021. Around 45 participants attended the webinar.
8. Webinar on "*Guava Cultivation: Prospects and Researchable Issues in Eastern Plateau and Hill Region*" on 3 August 2021. About 210 participants from different parts of the country participated in the webinar.
9. National e-workshop & stakeholder meet on "*Medicinal Plants in Eastern India: Prospects and Constraints*" on 6 August, 2021. A total of 225 participants including the state department officials, KVK scientists, medicinal plant growers, buyers, students, NGOs and academicians, traditional medical practitioners have participated in the e-workshop.
10. Workshop cum training program on "*Business Development in FPOs*" on 8 August 2021 at Kurghee Panchayat Secretariat, Itki, Ranchi. Total of 106 farmers from UP, Bihar, WB and JH participated in the event.
11. Webinar on "*Nutritional and Reproductive Interventions in Livestock Production*" on 10 August, 2021. About 180 stakeholders participated in the event.
12. Meeting of the Task Force Committee on "*Strategies for Agricultural Development in Middle Gangetic Plains*" on 17 August, 2021. Around 45 officials of CAU, SAUs, ICAR institutes and line departments of Bihar and Eastern UP attend the meeting.
13. Webinar on "*Mrida vihin kheti: Smart Krishi ki disha me ek sarahniye prayas*" on 23 August, 2021. Total 110 participants attended the webinar.
14. National Seminar on "*Rice-fallow Management in*

Eastern India" on August 26, 2021. The Seminar was attended by a total of 405 registered participants (from 26 states of India, Nepal, Germany and USA)

15. Webinar on "*Agricultural Residues Conversion to Biofuels through Solar Powered Micro wave Pyrolysis*" on 27 August, 2021. Total 144 participants attended the webinar.
16. National webinar on "*Recent Advances in Animal Genetics for Improving Poultry Productivity*" on 28 August, 2021. Total of 92 participants attended the webinar.
17. Review meeting of DBT KISAN HUB project was organized on 28 August, 2021. Around 50 officials of SAUs, ICAR institutes and NGOs of Bihar and Jharkhand attended the meeting.
18. Webinar on "*National Campaign on System Diversification in Aquaculture 'Recirculatory Aquaculture System and Biofloc Technology*" on 1 September, 2021. More than 164 farmers, entrepreneurs and students were participated in the programme
19. Webinar on "*Nutritional Security in India: Issues and Way Forward*" on 4 September, 2021. A total of 175 participants including the Scientists, State Department Officials, KVKs official, Students, NGOs and Academicians from the states of Bihar, Jharkhand, Chhattisgarh, Uttar Pradesh, Uttarakhand, Andhra Pradesh, Rajasthan, Odisha, Haryana, New Delhi, Sikkim, Maharashtra, Jammu and West Bengal participated in the Webinar.
20. National Webinar on "*Scientific Goat Farming: From the Livelihood to Financial Security for the Farmers*" on 18 September, 2021. More than 270 participates attended the webinar.
21. National Webinar on "*Entomophagy for Livelihood Security and Ecological Engineering for Innovative Pest Management*" on 22 September, 2021. Total 497 participants attended the webinar.
22. Webinar on "*Krishi me Nanotechnology ka Upyog: Nano-fertilizer*" in collaboration with IFFCO, Patna on 23 September, 2021.
23. Webinar on "*Agricultural Residues Conversion to Biofuels through Solar Powered Microwave Pyrolysis*" on 27 September, 2021.
24. Webinar on "*Role of Information Technology Management (ITM) for Enhancing Agricultural Productivity*" on 30 September, 2021. About 190 participants attended the webinar
25. Interface meeting on "*Animal Genetic Resources of Jharkhand*" on 4 October, 2021 with officials of Animal Husbandry, Govt. of Jharkhand.
26. National e-Conference on "*Integrated Farming Systems: A tool for enhancing income and nutritional security*" during 5-7 October, 2021. More than 500 participants attended the webinar.
27. National Webinar on "*Important Animal Diseases and their Control Program in India*" on 23 October, 2021. More than 1100 participates attended the webinar.
28. Webinar on "*Crop Diversification: A Way Towards Nutritional Security*" on 26 October, 2021. More than 180 participants attended the webinar.
29. Webinar on "*Strategies to Attain Sustainability in Agriculture*" on 29 October, 2021. More than 50 participants attended the webinar.
30. Webinar on "*Decision Support System (DSS) for Water Resources Planning & Management in agriculture*" on 1 November, 2021. More than 110 participants attended the webinar.
31. National webinar on "*Use of Solar Energy and Information Technology in Agriculture*" on 20 November, 2021. More than 140 participants attended the webinar.
32. National webinar on "*Geospatial Approach for Water Management in Urban and Rural Areas*" on 3 December, 2021. More than 110 participants attended the webinar.
33. National webinar on "*Furrow Irrigated Raised bed Planting (FIRB) for Improving Water Productivity*" on 21 December, 2021.
34. Webinar on "*Role of Information Technology Management (ITM) for Enhancing Agricultural Productivity*". More than 100 participants attended the webinar.

21. Events Organized

Organized Agriculture and Environment: the Citizen Face' under the Umbrella 'Azadi Ka Amrit Mahotsav

A campaign entitled 'Agriculture and Environment: the Citizen Face' under the umbrella '*Azadi ka Amrit Mahotsav*' was organized at ICAR RCER Patna on 26.11.2021. Total 34 students of classes IX, X, XI and XII from the BMP High School, Patna attended the program. Various events such as quiz and drawing competitions, visit to farm etc. were organized. To encourage the students, prizes were distributed.

Celebrated World Food Day 2021 at Ladaur, Muzaffarpur

On the occasion of world Food Day 2021, a training cum *kisan goshthi* on "Agricultural Resources Management in Flood Prone area" was organized at Ladaur, Muzaffarpur on 16.10.2021. In this programme, around 50 farmers participated. Farmers were sensitized with water management strategies, livestock health management and aquaculture resources management in flood-prone areas.

Celebrated World Water Day 2021

World Water Day 2021 was celebrated at ICAR RCER Patna on 22nd March 2021. About 40 farmers from nearby villages participated in this programme. Farmers were sensitized about the importance of water in our life and measures to adopt for sustainable use of water.

Organized Field Day under SCSP Project

ICAR-Research Complex for Eastern Region, Patna, in conjunction with KAUSHALYA Foundation, handed Knapsack Sprayers to SC farmers (300 no.) in the Nawada district of Bihar on 10-11th September, 2021, as part of the Government of India's Scheduled Castes Component (Scheduled Castes Sub-Plan). During the programme, Scientists from ICAR- RCER, Patna and representative from KAUSHALYA Foundation were present. The benefitted farmers were chosen from 16 villages in Sridala Block and 10 villages in Meskaur Block, Nawada. KAUSHALYA Foundation conducted an inventory survey in the selected block (SC dominated) prior to selecting farmers in order to find the most needy and hardworking farmers.

Demonstration cum training Programme on Small Interventions in Agricultural Practices for Doubling Income" under SCSP Project

Three days farmer's training programme on "Small interventions in agricultural practices for doubling income" was organized during 28-30 July, 2021 at ICAR-RCER, Patna with objective to improve the livelihood of schedule caste (SC) community. The training was organized under the Schedules Caste Sub-Plan (SCSP) of the Institute. The training was inaugurated by Dr Ujjwal Kumar, I/C Director of the Institute. Dr Ujjwal Kumar suggested farmers to adopt small interventions in different agricultural practices, so that they could get maximum output as well as maximum benefit. This training programme covered a range of topics related to doubling farmer's income. Total 210 farmers (both men and women) from Naubatpur block, Patna were participated in the training progarmme. At the end of training programme, sanitary materials (White towel) distributed among all the selected farmers. A filed visit was organized and farmers visited various experimental plots and got acquainted with the latest production technologies.

Organized Special National Swachhta Campaign

ICAR Research Complex for Eastern Region, Patna organized the Swachhta Campaign at Khaira block, Jamui District of Bihar on 12th October, 2021 with an aim to spread awareness about 'Swachchta' and its implementation across the country; also to focus on the role of the farmers in taking a leadership role for sanitation initiatives.

Front line demonstration of Rice varieties through FPO in East Champaran District

Under the NASF Project "*Development and Validation of Need Based Technology delivery model through FPO in Eastern Region of India*" frontline demonstration of rice (*varieties: Swarna Shreya, Swarna Samridhhi and Swarna Shakti*) was conducted in *Chiraya* and *Sangrampur* Blocks of East Champaran, Bihar on 4th September 2021.

Under the project 7.6 quintals of *Swarna Shreya*, 2 quintals of *Swarna Shakti* and 2 quintals of *Swarna Samridhhi* rice breeder seeds were distributed among the farmers during the onset of *kharif* 2021 as a part of seed production program. It was sown in 43 ha of land in farmers' field in the two blocks. The Rice breeder, Dr Santosh Kumar, Principal Investigator of the NASF project, Dr Anirban Mukherjee, CO-PI, Dr Kumari Shubha along with 60 farmers from Chiraiya, Sangrampur and Ghorasahan block attended the FLD program and learned first-hand knowledge about the drought tolerant rice varieties.

Front Line Demonstration of Wheat variety HD-2967 and FGD in East Champaran District

Under the NASF Project "Development and Validation of Need Based Technology delivery model through FPO in Eastern Region of India" frontline demonstration of Wheat variety HD-2967 was conducted in Chiraya and Sangrampur blocks of East Champaran, Bihar on 5 February 2021. In this programme Dr Anirban Mukherjee, Dr Kumari Shubha, Dr Sonaka Ghosh and Mr. R.K. Ray conducted the FLD followed by Focused Group Discussions with 23 farmers of Chiraya and 22 farmers of Sangrampur villages.

Organized NASF Advisory Committee meeting and field visit to FPO farmers in East Champaran, Bihar

Under the project "*Development and Validation of Need Based Technology Delivery Model Through FPO in Eastern Region of India*" funded by NASF, Advisory Committee meeting and field visit to FPO farmers in East Champaran, Bihar was organized by ICAR-RCER, Patna during 30-31 October, 2021. Former Advisor (Agriculture) and eminent extension specialist Dr V.V.

Sadamate and Professor, Agricultural Extension, BHU, Varanasi and Advisory Committee Member, Dr A.K. Singh, graced the occasion. The in-house meeting of the committee was conducted on 30th October, 2021 at ICAR-RCER, Patna and Field visit on 31st October 2021, in which Principal Investigator of the project, Dr Anirban Mukherjee and CCPIs from ICAR-RCER RC, Ranchi; IIVR, Varanasi and UBKV, Cooch Behar presented their progress report. Dr Sadamate appreciated the progress and advised the team to focus on strengthening of FPO by developing linkage with NABARD or other implementing partners like SFAC, NCDC etc. Dr A.K. Singh advised the team to make the FPO a role model so that others can see and learn the model of technology delivery. Earlier Dr Ujjwal Kumar, Director, ICAR-RCER, Patna welcomed the experts and briefed them about the institute activities related to technology backstopping. All the CCPIs and 50 farmers of the FPO attended the meeting.

Organized Live Telecast of Address by Hon'ble Prime Minister, Govt. of India on Natural Farming and Farmers-Scientist Interaction Meeting

On the occasion of Pre-Vibrant Gujarat Summit-2021, a programme was organized for farmers in which live telecast of address by Hon'ble Prime Minister, Govt. of India on Natural Farming was shown to them on 16th December, 2021. A total of 80 farmers from Patna district of Bihar participated in this event along with 50 scientists/staff of the institute. All the staff and farmers viewed the speech of Hon'ble PM, Hon'ble Union Minister of Agriculture and Farmers Welfare and other dignitaries on latest development in agriculture sector with special reference to Natural Farming.

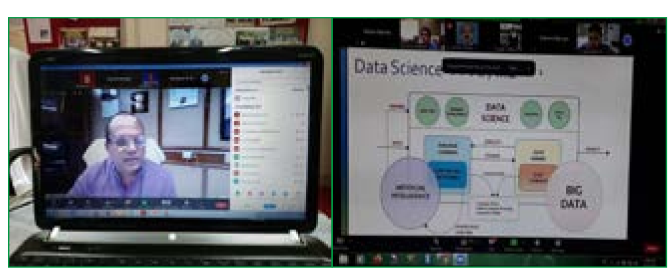
The programme was followed by a Farmers-Scientists Interaction Meet in which Heads of Division and other scientists of the institute answered the queries of farmers on agriculture and animal husbandry related issues. Director, ICAR-RCER, Dr Ujjwal Kumar in his address, motivated farmers to adopt natural farming practices in order to save natural resources like soil and water. He also advised farmers for judicious use for fertilizers and chemicals for quality output and natural resource conservation.

Organized Webinar on Ecosystem for Sustainable FPO

ICAR- Research Complex for Eastern Region, Patna organized a webinar on "Ecosystem for Sustainable FPOs" on 30th July, 2021 in online mode as a part of "*Azadi ka Amrut Mahaotsav*" to commemorate 75 years of India's Independence. Dr. Ujjwal Kumar, Director (A) inaugurated this webinar and welcomed all the delegates and audience. Lead speaker of the webinar, Dr. G.V. Ramanjaneyulu, Expert Director, Sahaja Aharam Producer Company and Executive Director of Center for Sustainable Agriculture delivered a very informative presentation on "Developing Sustainable Ecosystem for FPOs in India". Another eminent speaker Dr Ranjit Kumar, Head, Division of Agri Business Management, NAARM, Hyderabad delivered lecture on "Ecosystem and Policies Promoting FPOs in India". Both the expert speakers interacted with FPOs and policy makers present in the webinar and answered their queries. There were around 270 participants registered for the webinar from all parts of the country and got benefited through the lecture followed by discussion with the speakers. The webinar was organized with the active coordination by the team of scientists- Dr. Abhay Kumar, Dr. RC Bharti, Dr. Anirban Mukherjee, Dr. D.K. Singh and Dr Rohan Kumar Raman.

Organized Webinar on Artificial Intelligence for Smart Agriculture

ICAR-RCER, Patna organized an online webinar on *Artificial Intelligence (AI) for Smart Agriculture* on 22nd July 2021 as a part of "*Bharat ki Azadi ka Amrut Mahaotsav*". The major objective was to create awareness and update the knowledge of scientist, faculties, students and stakeholders regarding use of AI in agricultural sector. The chief guest of the event, Dr. S.K. Chaudhari, DDG, NRM, ICAR inaugurated the webinar. He stressed upon the use of new technologies for precision agriculture, practical implication of AI, recent concept of AI. He also explained the dimensions of smart agriculture. Dr. Chaudhari motivated the participants to learn about this new technology and urged to apply the same for enhancing productivity and quality output of Indian Agriculture. At the outset, Dr. Ujjwal Kumar, Director (A), ICAR-RCER, Patna welcome the chief guest and eminent speakers of the event and briefed about the technical programme. During the webinar, three speakers Dr. R. N. Sahoo, Principal Scientist, ICAR-IARI, New Delhi; Dr. D.C, Mishra, Senior Scientist, ICAR-IASRI, New Delhi and Mr. Alokesh Ghosh, Associate Director, C-DAC, Kolkata delivered lectures on Sensing and Data Analysis for Smart Agriculture, Application of AI in Agricultural Data Analysis and Robotics in Agriculture: An Indian Perspective, respectively. There were around 300 participants registered for the webinar from all over India and got benefitted through the lectures followed by discussion with the experts.



22. Krishi Vigyan Kendra

Krishi Vigyan Kendra, Buxar

Cluster Frontline Demonstration (CFLD) Conducted on Pulses and Oilseeds

KVK, Buxar conducted cluster front line demonstration on pulses funded by National Food Security Mission and oilseeds funded by National Mission on Oilseed and Oil Palm. The details of crop, technologies and beneficiaries are given below:

S. No.	Crop	Technology	Area (ha)	No of beneficiaries			Villages covered
				Male	Female	Total	
1.	Pigeonpea	IPA 203+seed treatment with FIR+foliar spray of micronutrient (MO and B) @1ml/lit water before flowering and management of Legume pod borer (*Maruca vitrata*) using Emamectin benzoate 10 g/15 lit water	10	28	9	37	Dhansoi, Gajrahi, Nadav, Jaso, Pawani, Majhariya, Ahirouli,Sonpa
2.	Chickpea	Pusa 3043+seed treatment with FIR+foliar spray of micronutrient (MO and B)@1ml/lit. water before flowering and management of gram pod borer (*Helicoverpa armigera*) by using bioinsecticide.	10	41	4	45	Mathila, Sujayatpur, Basahi, Majhariya, Indoor, Mahdah, Bocsa, Jalilpur, Lalganj
3.	Lentil	IPL 316 + seed treatment with FIR + management of aphid (*Aphiscraccivora*) by using bioinsecticide	10	35	3	38	Pawani, Pandeypatti, Bocsa, Barri, Jigna, Dafadehri, Chotki Basouli, Lalganj
4.	Mustard	RH 725/PM 31 + Soil application of sulphur 20 kg/ha and management of aphid (*Lipaphiserysimi*) by using bio-insecticide	40	109	6	115	Ahirouli Pawani, Chunni, Niyajipur, Badka Rajpur, Mahdah, Hukha, Lalganj, Sondhila
5.	Green gram	IPM 2-3+seed treatment with FIR+foliar spray of micronutrient (MO and B) @1ml/lit water before flowering and management of white fly by using Thaimathoxam 5g/15 lit water or Acetamiprid 15 g/15 lit water.	10	46	4	50	Chotka Rajpur, Pawani, Harpur, Barri, Kukurah, Khiri, Atav, Chakrahasi



Fig. 22.1. A view of CFLD plot at farmer's field

Front Line Demonstrations Conducted

FLDs on new varieties of major crops and production technologies, details of which is given in following table.

S. No	Crop	Technology	Area (ha)	No of beneficiaries			Village covered
				Male	Female	Total	
1.	Rice	Drought tolerant rice variety Swarna Shakti	5	9	1	10	Ramobariya, Harikishunpur, Geruabandha, Chotki Dhakaich
2	Rice	Drought tolerant rice variety Swarna Samridhi	5	10	1	11	Balapur, Chakrahasi, Geruabandh, Harikishunpur, Chotki Dhakaich,
3.	Rice	Drought tolerance rice variety *SwarnaShreya*	2.5	3	0	3	Churamanpur, Chotki Basouli, Harikishunpur
4	Rice	Short Duration Rice Variety CO 51	10	20	1	21	Jalilpur, Sondhila, Churamanpur, Pawani
5.	Wheat	ZT sowing of wheat variety HD 2967	5	19	0	20	Khandricha, Dhansoi, Mahdah, Geruabandh, Lalganj, Pandeypatti,
6.	Wheat	Zinc Bio fortified variety BHU 31 & BHU 25	5	6	7	13	Mahdah, Murar, Hukha, Nathpur, Kathar Khurd
7.	Vegetable Cowpea	Organic cowpea production var Kashi Kanchan	1	14	14	28	Hukha, Lalganj, Mathiya, Ekderva, Dalsagar
8	Waste Decomposer	Decomposition of rice crop residue	32	40	-	40	Pandeypatti, Indoor, Kukurah, Mahdah, Ramobariya, Harikishunpur
9	Okra	Demonstration of high yielding okra variety var Kashi Shristi	1	38	0	38	Jigna, Dalsagar, Churamanpur, Ramobariya
10.	Vegetable Pea	Demonstration of high yielding vegetable pea var. Azad Pea 3	-	12	0	12	Dalsagar, Nathpur, Ekderva
11.	Nutritional Garden	Nutritional Garden kit	-	90	60	150	Bharchakiya, pandeypatti, Vishrampur, Lalganj, Hukha, Pawani, Chunni, Rajpur

Fig. 22.2. Field view of frontline demonstrations

Demonstration under SCSP

SCSP programme was implemented by KVK, Buxar in which inputs for kitchen garden and backyard poultry were provided to SC farmers of the district.

S. No	Crop	Technology	No of beneficiaries			Village covered
			Male	Female	Total	
1.	Kitchen Garden	Vegetable seed	141	150	291	Hukha, Pandeypatti, Pawani, Gurudas Mathiya, CHotka Rajpur
2.	Backyard Poultry	Vanraja poultry strain	30	78	108	Chousa, Hukha, Nathpur, Mathiya

Training Programmes organized

Following trainings were organized by KVK, Buxar for dissemination of agricultural techniques to farmers and other stakeholders. Details of trainings conducted is given below:

Off Campus Farmers Training Programme

S. No.	Topic	No. of trainings	No of beneficiaries		
			Male	Female	Total
1	Crop Production Technologies	27	647	51	698
2	Seed Production	17	335	106	441
3	Plant Protection	26	629	84	713
4	Soil Science and Nutrient Management	23	517	59	576

Training Programme for Extension Functionaries

S. No.	Topic	Date	No of beneficiaries		
			Male	Female	Total
1.	IPM: Principle and practices	11-13 Feb., 2021	23	0	23
2.	Importance of organic farming and organic input production for soil and nutrient management	15 March, 2021	38	0	38
3.	In-situ crop residue management.	23 March, 2021	25	0	25

Training Programme for Rural Youth

S. No.	Topic	Date	No of beneficiaries		
			Male	Female	Total
1.	Income generation through Mushroom Production	1-5 Feb., 2021	17	3	25
2.	Production of high value crops (Onion, Mangrella, Potato and Mentha)	24-26 Feb., 2021	25	0	25
3.	Income generation through Mushroom production	25 Feb. to 1 March, 2021	13	2	15
4.	Production technology of vermicompost for rural youth	27 Feb- 3 March, 2021	20	0	20
5.	Seed production of *rabi* pulses	15-20 March, 2021	23	2	25
6.	Income generation through mushroom production	16-20 March, 2021	9	6	15



Fig. 22.3. View of off campus and on campus training programmes conducted by KVK

Fig. 22.4. View of on campus training programme for Rural Youth and distribution of certificates

Training Programmes Under CRP on FM & PF (Consortia Research Platform on Farm Mechanization and Precision Farming)

S.No	Topic	Date	Place	No of beneficiaries		
				Male	Female	Total
1	Popularization of RCT	March 8-10, 2021	KVK Buxar	34	12	46
2	Repairing maintenance and operation of tractor	Aug. 11-13, 2021	KVK Buxar	15	12	27
3	Repairing maintenance and operation of tractor	Aug. 17-19, 2021	KVK Buxar	21	0	21
4	Repairing maintenance and operation of tractor	Sept. 23-25, 2021	KVK Buxar	20	0	20
5	Repairing maintenance and operation of tractor	Sept. 28-30, 2021	KVK Buxar	20	0	20


Fig. 22.5. Training organized under CRP on FM & PF

On Farm Trials Conducted at KVK, Buxar

S. No.	Topic	Village covered	No of beneficiaries		
			Male	Female	Total
1	Effect of microbial inoculation (Azospirillium and PSB) and zinc fortification on growth, yield and economics of pearl millet	Badka Rajpur, Ahirouli, Harikishunpur Ramobariya	9	1	10
2	Assessment of seed dressing with Azotobacter and PSB and micronutrient Zn and B application on yield and economics of mustard	Harikishunpur, Pawani, Ramobariya	9	1	10
3	Evaluation of late sown chickpea Variety in Buxar district	Dafa Dehri, Pawani, Chunni, Kukurah	9	1	10
4	Evaluation of biofortified wheat varieties in Buxar district	Pandeypatti, Pawani, Mahdah	10	0	10
5	Assessment of new combination of insecticide against *Helicoverpa* in chickpea crop	Ramobariya,	6	0	6
6	Assessment of new chemical molecules for the management of rice stem borer (*Scirpophaga incertulas)*	Harikishunpur	6	0	6
7	Management of fall army worm (*Spodoptera frugiperda*) in maize	Ramobariya	6	0	6
8	Assessment of different crop establishment method on yield of lentil in rice-lentil cropping system	Harikishunpur, Dalsagar, Kukurah, Ramobariya	10	0	10
9	Effect of zinc and biofertilizer application on yield and yield attributes of green gram	Barri, Pandeypatti, Mahdah, Kukurah	10	0	10


Fig. 22.6. Field view of different On Farm Testing at farmers field

On Farm Trials under KVK-CSISA Project

Topic	No of beneficiaries	Place
Direct Seeded rice under Vattar conditions	10	
Weed management in direct seeded rice	10	Indapur, Rajapur, Mahdah, Chotki Basouli, Gerua bandh
Effect of rice crop establishment methods on the growth and yield of wheat	5	Konawali, Mango dehri, Geruabandha
Reduction in seed rate of rice using rice nursery enterprises	10	Bocsa, Mahdah, Geruabandha, Diwan ka Badkagaon
Performance of timely sown and late sown wheat varieties under different sowing schedules across ecologies	10	Rajapur, Konawali, Basahi, Bocsa, Chotki Basouli, Mahdah, Mango dehri, Chougai, Gerua bandh
Assessing the role of additional irrigation during terminal heat stress period during grain filling stage to beat the heat stress and its effect on wheat productivity	10	Rajapur, Konawali, Basahi, Bocsa, Chotki Basouli, Mahdah, Mango dehri, Chougai, Gerua bandh

Seed Hub Programme

KVK, Buxar produced the quality seed of chickpea crop under seed hub programme. Details of participatory seed production is given below:

S. No	Crop/ Variety	Area (ha)	Produc-tion (q)	Type of Seed	No of beneficiaries		
					Male	Female	Total
1.	Chickpea/ RVG 202	6.5	90	CS	10	0	10
2.	Chickpea/ Pusa 3043	1.3	9.20	FS	1	0	1
3.	Lentil IPL 316	9.25	121	FS	15	0	15
4.	Pigeonpea/ IPA 203	2.25	40	TL	6	0	6

Training Programme on Integrated Nutrient Management

A 15 days certificate course on Integrated Nutrient Management was organized for fertilizer dealers from 2-20 Dec, 2021. Total number of 38 male and 1female input dealers was enrolled for this training programme. It was inaugurated DDC, Buxar, Dr Yogesh Kumar Sagar and DAO Buxar Shri Manoj Kumar. Experts of KVK, Buxar, KVK, Bhojpur, VKS college of Agriculture, Dumraon, ICAR RCER, Patna delivered lectures on plant nutrient management, crop production, sustainable soil management, fertilizer acts etc.

Fig. 22.7. View of training programme on INM

Visit of Secretary Department of Agriculture, Government of Bihar

Secretary, Department of Agriculture, Govt of Bihar Dr N Saravana Kumar visited the KVK Buxar on 25th September, 2021. He visited the long term experimental


Fig. 22.8. Visit of Secretary, Department of Agriculture, Govt. of Bihar

trial of KVK Buxar under CRAP project, ongoing experimental trials, and different activities of KVK, Buxar. He also interacted with the farmers of CRAP villages and visited the demonstration plots at farmer's field. DM Buxar, DDC Buxar, Director ICAR RCER, Patna, Joint Director Agriculture, DAO Buxar, ADHO Buxar were also present in the programme.

Performance of Custom Hiring Centre under CRP on FM & PF Project at KVK Buxar

Custom hiring centre is currently operational at KVK, Buxar. This year, implements viz. Tractor, Multi-crop Thresher, Rotavator, Seed drill, Disc plough, Power harrow, Post hole digger, Knapsack sprayer, Planker, Case wheel were hired by progressive farmers of nearby areas. A total of 32 farmers were benefitted by using these machines which covered an area of 41 ha. Revenue of Rs 79,500/- was generated by the KVK, Buxar.

Fig. 22.9. Visit of NICRA village by the expert

Visit of Monitoring Team for NICRA Project

Dr Prabhat Kumar Pankaj, Principal Scientist, ICAR-CRIDA and Dr Amrendra Kumar, Principal Scientist ICAR-ATARI Patna visited in NICRA village on 21st October, 2021 and evaluated the ongoing activities under the project. The team members also interacted with the farmers regarding adaptation of technology and got the feedback related to climate resilient technologies adopted by the farmers.

Krishi Vigyan Kendra, Ramgarh

Cluster Front Line Demonstration (CFLD) on Pulse and Oilseed Crops

Cluster front line demonstrations were conducted under National Food Security Mission (NFSM) and National Mission of Oilseeds and Oil Palm (NMOOP) on new varieties and production technologies of horsegram, niger, sesame, field pea, mustard and lentil crops. Details of area covered and number of demonstartions on farmer's field is given below:

S. N.	Technology	No. of demo	Area (ha)
1	Horsegram:Variety- Birsa Kulthi 1 + Rhizobium culture seed treatment +line sowing, foliar spray of NPK 19:19:19 and use of neem oil	25	10
2	Niger: Variety- Birsa Niger-1, Seed treatment with *Trichoderma viridi*+ Line sowing+ IPMFoliar spray of NPK 19:19:19 and use of neem oil	50	20
3	Sesame:Variety- Shekhar, seed treatment with *Trichoderma viridi*+ line sowing+ IPM	50	20
4	Field Pea: Variety- IPF 4-9, Rhizobium culture seed treatment +line sowing, foliar spray of NPK 19:19:19 and use of neem oil	75	30
5	Mustard: Variety-Pusa Mustard-30 @5kg/ha, line sowing, (30X10cm) application of sulphur and foliar spray of NPK 19:19:19: @ 2.5kg/ha, spray of neem oil at the time of flowering @ 5ml/l water + Sulphur @2 g/l water	50	20
6	Lentil: Variety- HUL-57 @ 25kg/ha,Rhizobium culture seed treatment +line sowing, foliar spray of NPK 19:19:19 and use of neem oil	25	10

Front Line Demonstrations (FLDs)

FLDs on new varieties of drought resistance rice, black gram and some vegetables were laid out at farmers field. Details is given below:

Sl. No.	Technology	No. of farmers	Area (ha)
1	Paddy, Variety –Swarna Shakti Dhan (Drought resistance)	10	3
2	Paddy, Variety –Swarna Shreya (Drought resistance)	25	8
3	Black Gram, Variety- Birsa Urd -1	54	25
4	Bottle gourd var. Swarna Sneha (Popularization of downey mildew and powdery mildew tolerant variety)	10	1
5	Brinjal var. Swarna Shyamali (Wilt resistant)	10	1
6	Onion var. Arka Niketan (Popularization of var. for good shelf life)	10	1
7	Cow pea var. Swarna Mukut (Popularization of bush type variety with good yield)	10	1
8	Sponge gourd var- Swarna Sawani (Popularization of early flowering and fruiting satputiya)	10	1
9	Tomato var. Swarna Sampada (Popularization of bacterial wilt and early blight tolerant variety)	10	1
10	Paddy var. Sahbhagi, MTU 1010, IR 64 drt-1- (Popularization of drought tolerant cultivars of rice)	20	5

On-farm Trails (OFTs)

OFTs on Integrated pest Management, Information Technologies and Integrated Nutrient Management were conducted.

Sl. No.	Thematic Area	Technology Intervention	No. of farmers	Technology Options	Area (ha)
1.	IPM	Management of Fall Armyworm, *Spodoptera frugiperda* in maize	10	Farmers practice (Application of Carbofuran) T.O. I-i. Application of sand (After whorl formation and at 5% damage symptoms appearance) ii. Spraying of Emamectin benzoate 5SG @ 0.4g/l of water at 5 days of application of sand iii. Spraying of Thaimethoxam 12.6% + Lambda-cyhalothrin 9.5% @ 0.5 ml/ltr at 15 days of after 1st spray T.O.II - i. Application of soil (After whorl formation and at 5% damage symptoms appearance) ii. Spraying of Fipronil 5SC @ 1ml/l of water at 5 days of application of soil iii. Spraying of Spinosad @ 0.2 ml/l at 15 days of after 1st spray	1.0
2.	IPM	Assessment of module for thrips and sucking pest management in chilli crops	10	Farmers Practice (FP): TO-I: Rotational strategy of insecticides : Spray of Sporomesifen 22.9 SC @ 0.6 ml/l followed by Imidacloprid 17.8SC@0.5ml/l and Fenpropathrin 30 EC @ 0.6ml/l and Fipronil 80WDG @ 0.25 g/l and Emmamectin benzoate 5SG @ 0.5ml/l. TO-II: Integrated pest management strategy : Seedling root dip in Imidacloprid @2ml/l for sucking pests and first foliar spray of NSKE 4% 30 DAT and second foliar spray of imidacloprid 17.8 SL @ 0.5ml/l 40 DAT and third foliar spray of Fipronil 80WDG @0.25 g/l 50 DAT and fourth foliar spray of Emmamectin benzoate 25 WG @0.4g/l 60 DAT)	1.5
3.	ICT	Assessment of knowledge gain through Kissan Mobile Advisory for maize green cob grower	20	Farmers to farmers' knowledge sharing. (T1) Kissan Mobile advisory through Text messages of maize green cob cultivation. (T2) Kissan Mobile advisory through Audio of maize green cob cultivation. (T3) Kissan Mobile advisory through Video of maize green cob cultivation.	4.0
4.	ICT	Broccoli grower farmers gain knowledge through leaflet.	20	(T1) Broccoli cultivation through our own knowledge (T2) Broccoli cultivation after getting technical knowing through leaflet.	4.0

Sl. No.	Thematic Area	Technology Intervention	No. of farmers	Technology Options	Area (ha)
5.	INM	Integrated nutrient management in hybrid tomato (var. Swarna Sampada)	06	TO1:(FYM 100 q/ha; NPK 100:50:20) TO2: FYM (150 q/ha) + RDF N:P:K (200:100:80) TO2: FYM (150 q/ha) + RDF N:P:K (200:100:80) + Lime (3 q/ha)+ 2 spray of Boric acid (0.1%) and Zinc sulphate (0.1%)	01 ha.
6.	INM	Assessment of INM along with micronutrients application on yield and quality of mango cv. Amrapali	06	TO1: Farmers' practices- FYM @ 10 kg/tree + Urea 0.5 kg/tree (05 years old tree) after harvest. TO2: RDF + 0.2% ZnSO4 + 0.1% boric acid - 2 foliar spray (1before flowering and 2 at marble stage) TO3: RDF + 0.2% ZnSO4 + 0.1% CuSO4 + 0.1 % boric acid- 2 foliar spray 1) before flowering and 2) at marble stage. (RDF 0.5:0.5:0.3 NPK Kg/ tree (05 years old tree) + 100 g zinc sulphate + 50 g copper sulphate + 50 g boric acid (soil application) in basin after harvest).	72 Plants

Training Programmes Organized for Practicing Farmers and Farm Women/Rural Youth/ Extension Functionaries

S. N.	Title	Place	Date	No. of participants			
				SC	ST	Other	Total
1	Cultivation and management of button mushroom	Takha, Mandu	23.01.2021	5	3	7	15
2	Training on oyster mushroom cultivation	KVK Ramgarh	18.02.2021 to 19.02.2021	16	12	13	41
3	Training on "hybrid vegetable seed production"	KVK Ramgarh	23.06.2021	-	-	-	103
4	Training on seed treatment and use of fertilizer for black garm cultivation	KVK Ramgarh	28.06.2021	12	3	0	15
5	Training on "cultivation of blackgarm"	KVK Ramgarh	29.06.2021	7	5	17	29
6	Training on "cultivation of blackgarm"	KVK Ramgarh	07.07.2021	22	3	0	25
7	Training on "importance of nutrition for human body"	Badkachumba, Mandu	22.09.2021	21	3	11	35
8	Horticulture training and plant distribution under poshan maah	Badkagao	24.09.2021	26	2	6	34
9	Swachhata awareness	Bongahara, Mandu	12.10.2021	12	3	9	24
10	Training on "seed treatment of potato"	Indrabad, Mandu	15.10.2021	22	4	10	36
11	Training on "early farming technique"	Kundrukala, Mandu	16.10.2021	29	7	5	41
12	Preparation of compost	KVK Ramgarh	28.10.2021	8	5	12	25
13	Training on "integrated nutrient management" for fertilizer dealers	KVK Ramgarh	23.11.2021 to 08.11.2021	5	1	29	35
14	Agriculture and environment	Kasturaba Gandhi Balika High School, Mandu	26.11.2021	53	7	6	66
15	Modern techniques of cucurbitaceous vegetable production	Vill.- Gargali, Block-Mandu, Distt.-Ramgarh	5-3-2021	27	0	0	27
16	Techniques of protected cultivation of cucumber	Vill.- Indrabad, Block-Mandu, Distt.-Ramgarh	6-3-2021	29	0	0	29
17	Modern techniques of watermelon cultivation	Vill.- Indrabad, Block-Mandu, Distt.-Ramgarh	9-3-2021	29	0	0	29

S. N.	Title	Place	Date	No. of participants			
				SC	ST	Other	Total
18	Modern techniques of solanaceous vegetable production	Udlu village, Mandu block, Distt.- Ramgarh	10-3-2021	28	0	0	28
19	Off-season vegetables cultivation through low poly tunnel	Udlu village, Mandu block, Distt.- Ramgarh	12-3-2021	26	0	0	26
20	Use of plastics in vegetable farming	Udlu village, Mandu block, Distt.- Ramgarh	15-3-2021	27	0	0	27
21	Techniques of pruning of guava	Vill.- Indrabad, Block-Mandu, Distt.-Ramgarh	05-04-2021	26	0	0	26
	Household food security by kitchen gardening and nutrition gardening	Vill.- Gargali, Block-Mandu, Distt.-Ramgarh	6-4-2021	25	0	0	25
22	Advanced techniques of broccoli cultivation	Vill.- Jamundaha, Block-Mandu, Distt.-Ramgarh	12-4-2021	0	31	0	31
23	Techniques of planting material production of solanaceous vegetable	Vill.- Jamundaha, Block-Mandu, Distt.-Ramgarh	16-04-2021	0	30	0	30
24	Techniques of papaya cultivation	Village – Jamundaha, Mandu block, Ramgarh	15-05-2021	0	28	0	28
25	Techniques of cole crop vegetable production	Village- Jobla, Block- Mandu, District- Ramgarh	06-08-2021	0	29	0	29
26	Disease and pest management in paddy	Village-Gargali, PO-Mandudih, Block- Mandu, Ramgarh	31-08-2021	30	0	0	30
27	Leafy vegetable production during *rabi* season	Village- Korambe, Block- Gola, Ramgarh	21-09-2021	0	26	0	26
28	Plant propagation techniques of fruit	Village- Beecha and Lem, Block- Patratu, Ramgarh	06-10-2021	0	18	7	25
29	Importance and role of fruit plant in crop diversification	Village- Sutharpur, Block-Patratu, Ramgarh	18-10-2021	0	25	5	30
30	Processing and value addition of fruits and vegetable crops	Village- Kodi and Armadag, Block- Patratu, Ramgarh	22-10-2021	0	20	7	27
31	Micro irrigation systems in fruit and vegetable production	Village- Chhotkachumba, Block- Mandu, District-Ramgarh	02-11-2021	0	22	0	22
32	Production techniques of peas and faba bean	Village- Chhotkachumba, Block- Mandu, District-Ramgarh	15-11-2021	0	24	0	24

Skill Development Training

S.N.	Topics	Date	No. of trainees		
			M	F	Total
1.	Bee Keeping	05.02.2021 to 07.02.2021	07	06	13
2.	Recent techniques in nursery management and plant propagation of horticulture crops	02-06 Dec. 2021	27	13	40

Training under Scheduled Caste Sub Plan (SCSP)

S.N.	Title	Place	Date	No. of participants
1	Cultivation of vegetable through mulching technique	Indrabad	04.02.2021	26
2	Horticulture production	Indrabad	08.02.2021	28
3	Cultivation of summer vegetable	Indrabad	28.02.2021	42
4	Cultivation of summer vegetable	Govindpur	05.03.2021	25
5	Cultivation of cucurbitaceous vegetables	Govindpur	06.03.2021	25
6	Group farming	Govindpur	08.03.2021	23
7	Exposure visit	BAU, Ranchi	07.03.2021	50
8	Cultivation of summer vegetables	Govindpur	09.03.2021	15
9	Cultivation of brinjal and tomato	Udlu	15.03.2021	27
10	Mango orchard management	Udlu	15.03.2021	27
11	Grading of vegetables and marketing	Udlu	16.03.2021	28
12	Cultivation of Cucurbitaceous vegetables	Udlu	17.03.2021	28
13	Vegetable cultivation through drip irrigation	Udlu	18.03.2021	24
14	Cultivation of summer vegetables	Ichakdih	19.03.2021	47
15	How to Create linkage of farmers and producer groups	Indrabad	22.03.2021	50
16	Plant distribution	Indrabad	05.06.2021	28
17	Distribution of seed of rice variety-IR 64 DRT-1 among the farmers	Indrabad	19.06.2021	69
18	Water Management" and distribution of seed of rice variety-IR 64 DRT-1 among the farmers	Indrabad	24.06.2021	21
19	Backyard poultry management and distribution of ducklings	Indrabad	26.06.2021	42
20	Distribution of mango plants	Indrabad	29.06.2021	13
21	Distribution of blackgram variety Birsa urd-1	Indrabad	29.06.2021	78
22	Animal health camp	Indrabad	05.10.2021	44
23	Animal health camp and distribution of sickles	Indrabad	05.10.2021	43
24	Distribution of point guard plants	Indrabad	09.11.2021	14
25	Poultry production	Indrabad	17.11.2021	39
26	Model village Indrabad, Mandu under SCSP scheme	Indrabad	29.11.2021	35
27	Production and management of vegetable nursery	Indrabad	27.12.2021	16

Training Organized under Tribal Sub Plan (TSP)

S. N.	Title	Place	Date	No. of participants
1	Cultivation of summer vegetables	Tilaiya, Mandu	03.03.2021	26
2	Goatry management and cultivation of watermelon	Tilaiya, Mandu	06.03.2021	25
4	Cultivation and management of summer vegetable	Gadke	08.03.2021	25
5	Cultivation of cucurbitaceous vegetable	Tilaiya, Mandu	09.03.2021	25
6	Group farming	Chapari, Mandu	10.03.2021	23
7	Production of low volume and high value crops	Vill.- Jamundaha, Block-Mandu, Distt.-Ramgarh	12-4-21	31
8	Planting material production of horticultural crops	Vill.- Jamundaha, Block-Mandu, Distt.-Ramgarh	16-04-21	30
9	Techniques of papaya cultivation	Village – Jamundaha, Mandu block, Ramgarh	15-05-21	28

S. N.	Title	Place	Date	No. of participants
10	Techniques of *kharif* season vegetable production	Village- Jobla, Block- Mandu, District- Ramgarh	06-08-21	29
11	Disease and pest management in paddy	Village-Gargali, PO-Mandudih, Block- Mandu, Ramgarh	31-08-21	30
12	Leafy vegetable production during *rabi*	Village- Korambe, Block- Gola, Ramgarh	21-09-21	26
13	Plant propagation techniques of fruit	Village- Beecha and Lem, Block- Patratu, Ramgarh	06-10-21	25
14	Crop diversification	Village- Sutharpur, Block- Patratu, Ramgarh	18-10-21	30
15	Processing and value addition of horticultural crops	Village- Kodi and Armadag, Block- Patratu, Ramgarh	22-10-21	27
16	Micro irrigation systems in fruit and vegetable production	Village- Chhotkachumba, Block- Mandu, District- Ramgarh	02-11-21	22
17	Production techniques of peas and faba bean	Village- Chhotkachumba, Block- Mandu, District- Ramgarh	15-11-21	24

Training and Other Activities under Doubling Farmers Income (DFI)

S. N.	Title	Place	Date	No. of participants
1	Mushroom cultivation and management	KVK Ramgarh	10.02.2021	25
2	Training cum distribution of papaya plant	Takha, Mandu	11.02.2021	27
3	Mushroom cultivation and distribution of oyster spawn	KVK Ramgarh	03.03.2021	30
4	Production of tomato cultivation	KVK Ramgarh	02.08.2021	25
5	Production and management of onion cultivation	KVK Ramgarh	14.12.2021	26
6	Strengthening of SHGs	KVK Ramgarh	15.12.2021	25

Training Programme on Integrated Nutrient Management for Fertilizer Dealers, Pacs Members and Unemployed Youth

Training programme	Venue	Date	Course Coordinator
Integrated nutrient management training	KVK, Ramgarh	31 May – 14 Jun, 2021	Dr. Indra Jeet
		31 May – 14 Jun, 2021	Dr. Dharmjit Kherwar
		29 Jun-13 Jul, 2021	Dr. D.K. Raghav
		23 Oct-07 Nov, 2021	Dr. D.K. Raghav
		06-21 Dec, 2021	Dr. Indra Jeet

Sponsored/Vocational Training Programme Organized by KVK, Ramgarh

S. N.	Date	No of Course	Duration on Days	No of Participants			Sponsoring Agency
				M	F	Total	
1	25-27 Feb 2021	01	3	5	33	38	CRP on FM, ICAR-RCER Patna
2.	2-4, Aug, 2021	01	3	18	1	19	
3.	5-7, Aug, 2021	01	3	24	10	34	
4.	19-21 Sept, 2021	01	3	23	1	24	
5.	23-25 Sept, 2021	01	3	29	0	29	
6.	08-10 Dec, 2021	01	3	6	18	24	
7.	10-12 Dec, 2021	01	3	28	35	63	
8.	05-07 Feb, 2021	01	3	7	6	13	DHO, Ramgarh
9.	02- 06 Dec, 2021	01	05	27	13	40	

Establishment of Model Village Indrabad, Mandu under SCSP scheme

A Village was adopted by KVK Ramgarh under SCSP Scheme and developed as Model village as Atamnirbhar, Indrabad.This village has 43 Family belonging to SC category. The major cropping system was rice –fallow, goatry and forest produce collection. Major challenges were replacement of paddy variety, decrease the FMD and other infection in goat and large animals, increase the improved bird and ducks, increase the use of farm tools in agriculture operation and rice fallow area coverage through pulse and oilseed crops cultivation and early vegetables cultivation through pro tray and mulching. The following initiatives were taken as adoption of small farm machine tools for reducing drudgery in agriculture, Training for compost production, crop waste management and soil fertility mapping of village, post-harvest management, improving animal health through vaccination, deworming and promoting use of mineral mixture, formation of cluster youth entrepreneur for goat farming and milk production, backyard duck farming, Improving the cropping intensity and productivity though varietal replacement, Increase the high value vegetable production and value chain establishment, Formation of farmers club for capacity development of rural youth and attract rural youth towards agriculture etc.

- Due to vaccination of FMD and PPR the mortality rate is zero and distribution of Dewarmar and mineral mixture increase the body weight upto to 15-20% average of all goat and large animals.

- The distribution of paddy seed variety IR64-DRT-1 and Abhishek replace the old and traditional variety is 80 ha area and increases yield by 20% of village.

- The distribution of mustard vr. PM-30, chick pea and Lentil vr. HUL-57 for promotion of rice fallow coverage, more than 10 ha area covered by mustard variety, Chick pea vr. GNG 2144 in 3 ha area, lentil 2 ha was grown through zero tillage method to harvest the residual moisture.

- To increase the awareness about organic fertilizer compost unit was established in the village. More than 15 units have been started and farmer use their Agri-waste leaf fall of forest and cow dong.

- To create awareness about small farm mechanism tool use, distributed improved sickles, hand operated weeder, zero tillage machine and paddy thresher through custom hiring centre of KVK. It helped in reduction of drudgery and farmers have started timely sowing of crop after paddy harvest.

- Training and critical input as portray, coco pit, seed and chemical were provided to rural youth and they started the off season vegetables/crop cultivation as cucumber, watermelon, tomato, maize for green crop and fetch the profit of more than Rs. 50000 each by group of farmers.
- A farmers club was formed for regular planning and need of technology help, marketing linkage and capacity building. KVK play the major role by weekly monitoring of the activity in the village. It is the first village which developed by KVK as model village in coal mining area where major population of rural youth were unemployed now the rural youth and women are busy with backyard farming(Duck: Khaki Campbell, Bird: Kaveri) which is helping to fulfill the protein requirement of family.

Training on Integrated Nutrient Management (INM)

A total of five training programmes, each of 15 days duration, were organized on Integrated Nutrient Management (INM). Director, ICAR-RECR, Patna, Director, ATARI Panta Zone–IV and Head, ICAR-RCER, FSRCHPR, Plandu, Ranchi and other dignitaries interacted with the participants and provided valuable suggestions and information on efficient use of nutrients for healthy soil and crop. A total of 200 input dealers from Jharkhand participated. The training helped them to enrich their knowledge and skills regarding use of fertilizers for different crops.

23. Awards and Recognitions

Awards and Recognitions

- A K Singh, '**Fellow of Indian Society of Agronomy-2017**', by Indian Society of Agronomy, New Delhi.
- Akram Ahmed, **'Best Oral Presentation Award',** by Soil Conservation Society of India, New Delhi.
- Dhiraj Kumar Singh, '**Excellence in Extension Award-202**', by Agro Environmental Development Society (AEDS), Rampur, UP.
- Kumari Shubha, '**Research Excellence Award 2021**', by Institute of Scholars (InSc) Bengaluru, Karnataka
- Mandhata Singh, '**State Level Excellent Scientist Award**', by BAMETI, Patna.
- Manoj Kumar Tripathi, **'Outstanding PhD thesis Award', by** Society for Technology, Environment, Science and People, Kozhikode, India
- Manoj Kumar Tripathi, **'Young Scientist Award-2021',** by Society for Scientific Development in Agriculture and Technology, Meerut, UP
- Pankaj Kumar, '**Fellow, Society for Upliftment of Rural Economy**', by Society for Upliftment of Rural Economy Varanasi.
- **Rajni Kumari,** '**Inspiring Lady Veterinarian Award-2021**', under Research and Development category by "Pashudhan Praharee" on the occasion of International Women's Day.
- Rakesh Kumar, '**ISA Associateship Award 2020**', by Indian Society of Agronomy, New Delhi, India.
- Rakesh Kumar, '**NAAS Associates 2022**', by National Academy of Agricultural Sciences, New Delhi.
- Santosh Kumar, '**Distinguish Scientist Award**', by Society for Scientific Development in Agriculture and Technology (SSDAT), Meerut (UP).
- Santosh Kumar, '**Excellence of Research Award-2021**', by Agro Environmental Development Society (AEDS), Rampur (UP).
- Tanmay Kumar Koley, '**NAAS Associates 2021**', by National Academy of Agricultural Sciences, New Delhi.
- Arti Kumari, '**Certificate of Excellence in Reviewing**', by Journal of Geography, Environment and Earth Science International.
- Arti Kumari, '**Certificate of Excellence in Reviewing**', by Journal of Plant Cell Biotechnology and Molecular Biology.
- Pankaj Kumar, **'Member of CPCSEA'**, by committee for the purpose of control and Supervision of experiments on animals (CPCSEA), New Delhi
- Sanjeev Kumar, '**Certificate of Excellence**', by Asian Journal of Soil Science and Plant Nutrition
- Shanker Dayal, '**Nominee of CPCSEA**', by committee for the purpose of control and Supervision of experiments on animals (CPCSEA), New Delhi
- Ved Prakash, '**Certificate of Excellence in Reviewing**', by Asian Journal of Environment & Ecology.
- Ved Prakash, '**Certificate of Excellence in Reviewing**', by International Journal of Plant & Soil Science.

Best Paper/Poster/Presentation Awards

- Anirban Mukherjee, D.K. Singh, K. Pradhan, Kumari Shubha, Ujjwal Kumar and Ramnath K Ray, '**Best Oral Presentation Award**' for the paper entitled 'FPO as potential model for potato marketing and export in Eastern India' in International Potato e-Conference 23-26 November 2021 held at ICAR-CPRI, Shimla, H.P.
- Pankaj Kumar, **'Best oral presentation Award'**, by Society for Scientific Development in Agriculture and Technology, Meerut, UP.
- Rajni Kumari, '**Best Oral Presentation Award**, in International web Conference on "Global Research Initiatives for Sustainable Agriculture & Allied Sciences-2021", during 13-15 December 2021
- Rajni Kumari, '**Best Oral Presentation Award**', in National Seminar on "Innovative Biotechnological approaches for enhancing fertility, health and productivity of Livestock to boost the farmers economy" held at ANDUAT, Ayodhya during 17-18 Dec 2021
- RK Raman, Jaspreet Singh, Akram Ahmed, P.S. Brahmanand, Abhay Kumar, DK Singh, N. Bhakta, Ujjwal Kumar, Sudip Kumar, Anirban Mukherjee and Tanmay K. Koley, '**Appreciation Certificate for Oral Presentation**', in 30th National Web Conference on "Soil and Water Management Technologies for Climate Resilience, Agricultural and Environmental Sustainability" during 14-16, December, 2021, at Bhubaneswar.
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24. Publications

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Upadhyaya A. 2021. Possible strategies for improving food security through efficient land water and energy management in eastern region. Paper presented in 55th Annual Convention of ISAE and International Symposium on Emerging Trends in Agricultural Engineering Education, Research and Extension organized by ISAE, New Delhi and Dr. RPCAU and BAMETI from 23-25 November, 2021.

25. Personnel

Division of Crop Research

Scientists

Dr. J.S. Mishra, Pr. Scientist (Agronomy) & upto 25.11.2020

Dr. A.K. Choudhary, Pr.Scientist (Plant Breeding) & I/c Head

Dr. Sanjeev Kumar, Pr. Scientist (Agronomy)

Dr. Shivani, Pr. Scientist (Agronomy)

Dr. Md. Monobrullah, Pr. Scientist (Entomology)

Dr. Narayan Bhakta, Pr. Scientist (Plant Breeding)

Dr. Santosh Kumar, Sr. Scientist (Plant Breeding)

Dr. Rakesh Kumar, Scientist (Agronomy)

Dr. Surajit Mondal, Scientist (Soil Science)

Mr. Karnena Koteswara Rao, Scientist (Soil Science) (on study leave)

Dr. Abhishek Kumar Dubey, Scientist (Plant Pathology)

Dr. N. Raju Singh, Scientist (Agroforestry)

Ms. Manisha Tamta, Scientist (Agricultural Meteorology) (on study leave)

Dr. Kumari Shubha, Scientist (Vegetable Science)

Dr. Rachana Dubey, Scientist (Environmental Science)

Mr. Govind Makarana, Scientist (Agronomy)

Dr. Saurabh Kumar, Scientist (Microbiology)

Division of Livestock and Fishery Management

Scientists

Dr. Kamal Sarma, Pr. Scientist (Fishery) & I/c Head

Dr. A. Dey, Pr. Scientist (Animal Nutrition)

Dr. S. Dayal, Pr. Scientist (Animal Genetics & Breeding)

Dr. Pankaj Kumar, Sr. Scientist (Veterinary Medicine)

Dr. P.C. Chandran, Sr. Scientist (Animal Genetics and Breeding)

Dr. P. K. Ray, Scientist (Veterinary Pathology)

Dr. Rajni Kumari, Scientist (Animal Biotechnology)

Dr. Reena Kumari Kamal, Scientist (LPM) up to 10.10.2021

Dr. Tarkeshwar Kumar, Scientist (Aquaculture)

Dr. Manoj Kumar Tripathi, Scientist (Animal Physiology)

Mr. Surendra Kumar Ahirwal, Scientist (Fisheries Resource Management)

Sh. Jaspreet Singh, Scientist (FRM)

Dr. Jyoti Kumar, Scientist (Vet. Microbilogy)

Technical Officer

Dr. S. K. Barari, Chief Technical Officer

Sh. Dev Narayan, Technical Officer

Division of Land and Water Management

Scientists

Dr. A. Upadhyaya Pr. Scientist (SWCE) & I/c Head

Dr. A. Rahman, Pr. Scientist (Physics)

Dr. Anil Kumar Singh, Pr Scientist (Agronomy)

Dr. Bikash Sarkar, Pr. Scientist (FMPE)

Dr. Ajay Kumar, Pr. Scientist (SWCE)

Dr. Manibhushan, Sr. Scientist (Comp. App.)

Dr. P.K. Sundaram, Scientist (FMP)

Dr. Pawan Jeet, Scientist (L&WME)

Er. Akram Ahmed, Scientist (L&WME)

Dr. Kirti Saurabh, Scientist (Soil Science)

Mr. Ved Prakash, Scientist (Agril. Meteorology)

Mrs. Mridusmita Debnath, Scientist (L&WME) (on study leave)

Mrs. Arti Kumari, Scientist (L&WME)

Division of Socio-Economics and Extension

Scientists

Dr. Ujjwal Kumar, Pr. Scientist (Agril. Extension) & Head

Dr. Abhay Kumar, Pr. Scientist (Agril. Statatics)

Dr. R.C. Bharti, Pr. Scientist (Agril. Statatics)

Dr. N. Chandra, Pr. Scientist (Agril. Economics)

Dr. Tanmay Kumar Koley, Scientist (Horticulture)

Dr. Dhiraj Kumar Singh, Scientist (Ag. Extension)

Dr. Anirban Mukherjee, Scientist (Agril. Extension)

Dr. Rohan Kumar Raman, Scientist (Agil. Statistics)

Technical Officer

Mr. Sanjay Rajput, Technical Officer

Prioritization Monitoring & Evaluation Cell

Dr. A. Dey, Pr. Scientist (Animal Nutrition) & I/c PME Cell

Dr. Sonaka Ghosh, Scientist (Agronomy)

Technical Officer

Mr. Sarfaraj Ahmad, Sr. Technical Officer (Computer)

ARIS Cell

Dr. R.C. Bharti, Pr. Scientist (Agril. Statatics) & I/c ARIS

Technical Officer

Sh. Anil Kumar, ACTO

Farm Section

Mr. Abhishek Kumar, Assistant Chief Technical Officer

Mr. P.K. Singh, Sr. Technical Officer

Mr. R.K. Tiwari, Technical Officer up to 28.02.2022

Mr. A.S. Mahapatra, Technical Officer

Workshop and Estate Section

Sh. M.L. Swarnkar, Chief Technical Officer

ICAR RCER Farming System Research Centre for Hill & Plateau Region, Ranchi

Scientists

Dr. A.K. Singh, Pr. Scientist (Horticulture) & Head

Dr. R.S. Pan, Pr. Scientist (Horticulture)

Dr. B.K. Jha, Pr. Scientist (Horticulture)

Dr. Bikash Das, Pr. Scientist (Horticulture)

Dr. S. K. Naik, Pr. Scientist (Soil Science)

Dr. V.K. Yadav, Pr. Scientist (Ag. Extension)

Dr. Asit Chakrabarti, Sr. Scientist (LPM) up to 27.02.2021

Dr. S.S. Mali, Sr. Scientist (SWCE)

Dr. P. Bhavana, Sr. Scientist (Plant Breeding)

Dr. Ajit Kumar Jha, Sr. Scientist (Plant Pathology)

Dr. J.S. Choudhary, Scientist (Entomology)

Ms. Reshma Shinde, Scientist (Soil Science)

Dr. Reena Kumari Kamal, Scientist (LPM) w.e.f., 11.10.2021

Mr. P.K. Sarkar, Scientist (Agroforestry) up to 08.10.2021

Dr. M.K. Dhakar, Scientist (Fruits Science)

Dr. Meenu Kumari, Scientist (Veg. Science) w.e.f., 15.02.2021

Dr. Prerna Nath, Scientist (Food Technology) w.e.f., 01.11.2021

Technical Officers

Dr. G. P. Singh, Chief Technical Officer

Mr. Paul Sanjay Sircar, Assistant Chief Technical Officer (Computer)

Mr. Om Prakash, Senior Technical Officer (Civil)

Mr. Suresh Kumar, Senior Technical Officer (Farm)

Mr. Ganga Ram, Senior Technical Officer (Lab.)

Mr. Chandrakant, Senior Technical Officer (Lab.)

Mr. Chandra Shekher Prasad, Senior Technical Officer (Lab.)

Mr. Dhananjay Kumar, Technical Officer (Farm)

Mr. Arun Kumar, Technical Officer (Electrical)

Mr. Pradip Kumar Singh, Technical Officer (Laboratory)

Mrs. Anima Prabha, Technical Officer (Press & Editorial)

Mr. Vijay Kumar Singh, Technical Officer (Lab.)

Mr. Manual Lakra, Technical Officer (Farm)

Mr. Dev Charan Kujur, Technical Officer (Mechanical)

ICAR RCER, Research Centre for Makhana, Darbhanga

Dr. I.S. Singh, Pr. Scientist (Soil Science) & I/c Head

Dr. B.R. Jana, Scientist (Horticulture)

Dr. Manoj Kumar, Scientist (Soil Science)

Mr. Shailendra Mohan Raut, Scientist (FRM)

Mr. Padala Vinod Kumar, Scientist (Agronomy)

ICAR RCER, Krishi Vigyan Kendra, Buxar

Subject Matter Specialists

Dr. Deokaran, SMS (Soil Science)

Mr. Ramkewal, SMS (Plant Protection)

Dr. Mandhata Singh, SMS (Agronomy)

Dr. Hari Govind Jaiswal, SMS (Plant Breeding)

Technicals

Mr. Arif Parwez, Farm Manager (T-5)

Mr. Afroz Sultan, Programme Assistant (Lab. Tech.)/ T-5 up to 30.09.2021

Mr. Vikash Kumar, Programme Assistant (Computer)/T-6

ICAR RCER, Krishi Vigyan Kendra, Ramgarh

Subject Matter Specialists

Dr. Dushyant Kumar Raghav, SMS (Plant Protection)

Dr. Indrajeet, SMS (Ag. Extension)

Dr. Dharmjeet Kherwar, SMS (Agroforestry/ Horticulture)

Technical

Shri Sunny Kumar, Farm Manager

Administration & Finance Section

Mr. Pushpanayak, Chief Administrative Officer

Mr. K.K. Lal, AF&AO

Mrs. Prabha Kumari, AAO

Mr. Dayanand Prasad, AAO

Mr. Ravi Shankar, AAO

Mr. Rakesh Mani, Assistant

Mr. Md. Sajid Mustaque, Assistant (on deputation w.e.f. 19.12.2020)

Mr. Madan Paswan, Assistant

Ms. Divyadarshini, Assistant

Mr.. Nagendra Kumar, Assistant

New Joining

Scientists

Dr. Meenu Kumari, Scientist (Veg. Science) transferred from ICAR Central Horticulture Exprimentation Station, Bhubaneswar w.e.f., 15.02.2021

Dr. Prerna Nath, Scientist (Food Technology) transferred from ICAR CIPHET Ludhiana w.e.f., 01.11.2021

Transfer

Dr. Asit Chakrabarti, Sr. Scientist (LPM) transferred to ICAR RC for NEH Region, Umiam, Barapani w.e.f., 28.02.2021

Dr. Reena Kumari Kamal, Scientist (LPM) transferred to ICAR RCER FSRCH&PR, Ranchi w.e.f., 11.10.2021

Mr. P.K. Sarkar, Scientist (Agroforestry) transferred to ICAR RC for NEH, Reagion RC Lambucherra, Tripura w.e.f., 09.10.2021

Promotion

Scientists

Dr M.K. Dhakar, Scientist (Fruit Science) promoted to Scientist (Level-12) w.e.f. 01.01.2018

Dr T.L. Bhutia, Scientist (Vegetable Science) promoted to Scientist (Level-12) w.e.f. 01.07.2018

Mr. P.K. Sarkar, Scientist (Agroforestry) to Scientist (Level-12)

Smt. Reshma Shinde, Scientists promoted to Scientist (Level-12)

Technical

Mr. Sarfaraj Ahmad, Technical Officer (Level-7) promoted to Sr. Technical Officer (Level-10) w.e.f., 09.09.2020

Mr. Vikas Kumar, Technical Officer (Level-7) promoted to Sr. Technical Officer (Level-10) w.e.f., 17.08.2019

Mr. Anil Kumar, Sr. Technical Officer (Level-10) promoted to ACTO (Level-11) w.e.f., 09.09.2019

Administrative

Mrs. Ritu Rani, LDC promoted to UDC w.e.f., 18.12.2021 (AN)

Retirements

Sh. Manuel Lakra, Ex- TO, w.e.f. 28.02.2021

Late Bimal Linda, Ex- SSS expired on 28.04.2021

Sh. Paskal Lakra, Ex- SSS, w.e.f. 30.04.2021

Sh. Panchu Kachhap, Ex- SSS, w.e.f. 30.04.2021

Sh. Etwa Munda, Ex- SSS, 31.08.2021

Sh. Daswa Oraon, Ex- SSS, w.e.f. 30.09.2021

Sh. Tarkeshwar Mahto, Ex- SSS, w.e.f. 31.12.2021

26. On-Going Research Projects

Theme wise Ongoing and New Institute Research Projects 2021

Sl. No.	Project code	Project title	Name of PI & Co-PI	Start year	Comp year	Funding agency
Theme 1. Farming System Research including Climate Resilient Agriculture						
1.0	**Integrated Farming System and Cropping System for Eastern Region**					
1.1	ICAR-RCER/ AICRP/ IFS/EF/ 2010/ **25(i)**	Development of location specific Integrated Farming System models for small and marginal farmers of Bihar	Sanjeev Kumar A. Dey Ujjwal Kumar N. Chandra Kamal Sarma Shivani Ajay Kumar Kirti Saurabh	June 2010	Sep. 2025	AICRP on IFS
1.2	ICAR-RCER/ RC Ranchi/ 2011/ **25(iii)**	Development of location specific Integrated Farming System models for rainfed eco-system of Eastern Plateau Hill region	M.K. Dhakar S.K. Naik P.K. Sarkar Reena K. Kamal	June 2011	July 2023	ICAR RCER
1.3	ICAR-RCER/ RC Ranchi/ 2014/**147**	Development of multi-tier cropping system for rainfed uplands of eastern plateau and hills	M.K. Dhakar Reshma Shinde Bikas Das (Associate)	Sept. 2014	Sept. 2023	ICAR RCER
1.4	ICAR-RCER/ RC Ranchi/2019/**225**	Evaluation of Zero Budget Natural Farming (ZBNF) for Eastern Plateau and Hill Region	B.K. Jha P.K. Sarkar Reshma shinde S.K. Naik (Associate) J.S. Choudhary (Associate)	2019	2024	ICAR-RCER
1.5	ICAR-RCER/ RC Ranchi/2020/**237**	Development of multipurpose trees and medicinal plants based agroforestry models for Eastern Plateau and Hill Region	P.K. Sarkar Reshma Shinde M.K. Dhakar	2020	2025	ICAR-RCER
1.6	-	Optimum land allocation of different Integrated farming systems components to maximize resource use efficiency and net return.	Manibhushan A. Upadhyaya Sanjeev Kumar Bikas Das S.S. Mali	Sept.2020	Aug. 2023	ICAR-RCER
1.7	-	Consortia Research Platform (CRP) on Farm Mechanization and Precision Farming	Bikash Sarkar Ujjwal Kumar P. K. Sundaram Pawan Jeet Ramkewal D.K.Raghav	April 2016	Dec. 2021	ICAR

Sl. No.	Project code	Project title	Name of PI & Co-PI	Start year	Comp year	Funding agency
2.0	**Resource Conservation Technology**					
2.1	ICAR-RCER/ DCR/EF/2015/ **40**	Evaluation of Conservation Agricultural (CA) practices under Rice-fallow system of Eastern Region	Rakesh Kumar B. K. Jha S. K. Naik S.S. Mali Rachana Dubey S. Mondal	2015	2026	Consortium Research Platform on CA (ICAR)
2.2	ICAR-RCER/ DCR/EF/2016/	Cereal Systems Initiative for South Asia (CSISA) Phase III	Rakesh Kumar S Mondal Rachana Dubey G. Makarana Saurabh Kumar	2016	December 2021	CIMMYT
2.3	ICAR-RCER/ RC Ranchi/2011/ **196**	Evaluation of leaching loss of nutrients in acidic soils of Jharkhand under different cropping systems	S. K. Naik S. S. Mali	Oct 2018	Sept, 2021 Extd2023	ICAR RCER
2.4	--	Network project on Conservation of lac insect genetic resources (NPCLIGR)	M. Monobrullah	Jan 2019	March 2023	AINP on CLIGR
2.5	--	Impact of long- term conservation agriculture on greenhouse gas fluxes from middle Indo-gangetic plains of India.	Rachana Dubey N.Raju Singh G.Makarana	Aug.2020	July 2023	ICAR RCER
2.6	New	Soil organic carbon and crop productivity as influenced by tillage operations in India	Surajit Mondal	Dec 2020	Dec 2023	(SERB-DST funded)
3.0	**Climate Resilient Agriculture**					
3.1	ICAR-RCER/ DCR/ 2018/ **208**	Effect of water deficit and heat stress on wheat : changes in plant physiologi-cal traits and yield attributes	Rachana Dubey Santosh Kumar Ved Prakash	2018	2021 Extd2022	ICAR RCER
3.2	ICAR-RCER/ DCR/ EF/2018/	Long term conservation agriculture impact on micro biome and soil health indicators for resource efficiency and resilience in maize systems	Rakesh Kumar S. Mondal	Nov. 2018	Oct 2021	NASF
3.3	ICAR-RCER/ DSEE/ EF/2019/	Climate Resilient Agriculture Programme	Abhay Kumar Ujjwal Kumar M.Monobrullah P.K. Sundaram Rakesh Kumar Surajit Mondal Dhiraj Kumar Singh R.K. Raman	Nov. 2019	Mar. 2024	Govt. of Bihar
3.4	ICAR-RCER/ DCR/ EF/2019/	Climate-smart management for stress-prone environment	Santosh Kumar Rakesh Kumar Kirti Saurabh	2019	2022	(IRRI Funded)
3.5	ICAR-RCER/ DCR/ EF/2020/	Optimizing soil organic carbon stock in rice-based cropping system in irrigated ecosystem	Rachana Dubey S. Mondal	2020	2022	SERB-DST

Sl. No.	Project code	Project title	Name of PI & Co-PI	Start year	Comp year	Funding agency
3.6	New	Climate change impact studies at selected location in Bihar	Ved Prakash Kirti Saurabh Arti Kumari Sonaka Ghosh A. Upadhyaya	2021	2024	ICAR-RCER
Theme- 2. Genetic Resource Management and Improvement of Field, Horticultural and Aquatic crops						
4.0	**Varietal Development**					
4.1	ICAR-RCER / HARP/ 2001/ **03**	Plant genetic resource and improvement of fruit crops	M.K. Dhakar Bikash Das J. S. Choudhary D. Kherwar	2001	Long term	ICAR RCER
4.2	ICAR-RCER/ RCM/ 2015/	Evaluation of different genotypes of water chestnut	B.R. Jana I.S. Singh Manoj Kumar	2015	2020 Extd. 2021	ICAR RCER
4.3	ICAR-RCER/ RC Ranchi/ 2017/**215**	Genetic resource management in vegetable crops	A.K. Singh P. Bhavna R. S. Pan V.K. Yadav J.S. Chaudhary	Sept 2017	Long term project	ICAR RCER
4.4	ICAR-RCER/ DCR/EF 2017/	Frontiers in Rice Science (New Science), Sub Project 1: Resource remobilization during grain filling under drought (erstwhile Identification of traits, genes, physiological mechanisms to develop climate smart varieties for unfavourable environment)	Santosh Kumar	2017	2022	IRRI
4.5	--	Development of nutrient rich lines of pulse legumes for eastern India	A.K. Choudhary Kirti Saurabh	Sep. 2019	Aug. 2022	ICAR-RCER
4.6	ICAR-RCER/ DCR/2019/**227**	Evaluation, characterization and identification of rice genotypes for combine tolerance to drought and submergence	Santosh Kumar N. Bhakta	July 2019	June 2023	ICAR-RCER
4.7	ICAR-RCER/ RC Ranchi/ 2019/ **226**	Development of multiple disease resistant hybrids in solanaceous vegetables	P. Bhavana A.K. Singh A.K.Jha J.S. Choudhary	2019	2024	ICAR-RCER
4.8	ICAR-RCER/ RC Ranchi/ 2020/ **244**	Genetic enhancement of pigeon pea for yield and biotic stress resistance	P. Bhavana Kishor Tribhuvan (ICAR-IIAB) J S Choudhary A.K.Jha	June 2020	Dec 2025	ICAR-RCER
4.9	New	Improvement of French bean for rust resistance	Meenu Kumari R.S. Pan Ajit Kumar Jha	July 2021	June 2025	ICAR-RCER
4.10	New	Genetic enhancement of selected vegetable legumes for Eastern India	Kumari Shubha A.K.Choudhary A.K. Dubey R.S. Pan V.K. Padala	2021	2024	ICAR-RCER

Sl. No.	Project code	Project title	Name of PI & Co-PI	Start year	Comp year	Funding agency
4.11	New	Characterization of aquatic nut, Rhizome and tuber crps under wetland ecosystem of North Bihar	B.R.Jana I.S.Singh	2021	2024	ICAR-RCER
4.12	New	Development of high moisture tolerant pigeon pea and its agronomic practices for eastern India	Anil Kr. Singh A.K.Choudhary A. Upadhyay Kirti Saurabh M.Moborullah Pawan Jeet Yasin J.K. (NBPGR)	2021	2026	ICAR-RCER
Theme- 3. Improved Production and Protection Technologies for Agri-Horti Crops						
5.0	**Production Technologies**					
5.1	--	Creation of seed hubs for increasing indigenous production of pulses in India	A.K. Choudhary G. Makarana Hari Govind (KVK, Buxar)	2016	2021	ICAR
5.2	ICAR-RCER/ DSEE/ 2018/	Performance evaluation of medicinal and aromatic plant in EIGP	T.K. Koley N. Raju Singh N.A. Gajbhiye (DMAPR, Anand)	July 2018	June 2021 extd Mar 2022	ICAR-RCER
5.3	ICAR-RCER/ RCM/ 2019/	Response of nutrients on productivity of water chestnut and Indian lotus	I.S. Singh Manoj Kumar	Aug 2019	July 2022	ICAR-RCER
5.4	ICAR-RCER/ RCM/ 2019/	Effect of different intercultural practices on biochemical constituents of makhana seed	B.R. Jana Manoj Kumar	Aug 2019	July 2022	ICAR-RCER
5.5	ICAR-RCER/ RCM/ 2019/	Effect of secondary and micronutrients on yield and quality of makhana in field condition	Manoj Kumar I.S. Singh S.M. Raut	Aug 2019	July 2022	ICAR-RCER
5.6	ICAR-RCER/ DCR/ 2019/ **228**	Enhancing nutritional security of rural households through vegetable based Nutri garden in Bihar	Kumari Shubha T.K. Koley Akram Ahmed	Oct. 2019	Sep. 2022	ICAR-RCER
5.7	ICAR-RCER/ RC Ranchi/ 2020/**238**	Standardization of basin enrichment in bearing orchards of Bael, Mango and Guava under eastern plateau and hill region	Bikash Das P.K. Sarkar M. K.Dhakar	2020	2025	ICAR-RCER
5.8	ICAR-RCER/ DCR/ 2020/ **236**	Standardization of agro-techniques in nutri-cereals for enhancing the productivity in eastern Indo-Gangetic plains	Rakesh Kumar Surajit Mondal	July 2020	Dec. 2025	ICAR-RCER
5.9	New	Improving nutrient use efficiency and productivity by customizing nutrient application methods in Makhana	Manoj Kumar I.S. Singh	June 2020	May 2023	ICAR-RCER
5.10		Studies on soils in relation to makhana production in North Bihar	Manoj Kumar I.S. Singh	June 2020	May 2023	ICAR-RCER

Sl. No.	Project code	Project title	Name of PI & Co-PI	Start year	Comp year	Funding agency
5.11	New	Phosphorous mobilization through organic amendments in acidic soils of Hill and Plateau region	Reshma Shinde S.K. Naik A.K. Jha	2021	2026	ICAR-RCER
5.12	ICAR-RCER/ DCR/EF/ 2020/	Developing precision nutrient management protocols for rice-wheat-maize system in IGP	Surajit Mondal Rakesh Kumar	2020	2023	NASF
5.13	New	Evaluation of vegetable soybean for horticultural and nutritional traits	R S Pan Meenu Kumari Reshma Shinde Sujit Bishi (ICAR-IIAB, Ranchi)	July 2021	June 2026	ICAR-RCER
5.14	New	Development multitier mango orchard with shade loving spices and medicinal plants	N. Raju Singh T.K. Koley Ved Prakash	2021	2024	ICAR-RCER
5.15	New	Sustainable fodder production system under different nitrogen and zinc management practices in eastern India	G. Makarana Sanjeev Kumar Saurabh Kumar A. Dey	2021	2024	ICAR-RCER
5.16	New	Standardization of hydroponic technology for horticultural crops	T.K. Koley Kumari Shubha N. Raju Singh S.S. Mali Reshma Shinde P.K. Sundram A. Rahman	2021	2024	ICAR-RCER
5.17	New	Effect of nano-DAP fertilizer on the performance and yield of rice-wheat crop	Kirti Saurabh Santosh Kumar Ved Prakash Sonaka Ghosh A.K. Dubey	2021	2024	IFFCO
5.18	New	Development of technology for post-harvest management and value addition of jackfruit in Eastern region	Prerna Nath M.K. Dhakar Ajit K Jha S. J. Kale,IINRG	Jan, 2022	Dec, 2024	ICAR-RCER
6.0	**Protection Technologies**					
6.1	ICAR-RCER/ DCR/ 2018/**217**	Development of native *Trichoderma* based bioformulations for management of soil-borne diseases	A.K. Dubey A.K. Choudhary	2018	2021 Extd 2022	ICAR-RCER
6.2	ICAR-RCER/ RC Ranchi/ 2018/**198**	Seasonal incidence and evaluation of management strategies against insect- pests of cauliflower and chilli	J.S. Choudhary D.K. Raghav Md. Monobrullah Rakesh Kumar	2018	Dec 2021	ICAR-RCER
6.3	ICAR-RCER/ DCR/ 2019/ **229**	Studies on weed and seed bank dynamics in different cropping systems in the middle Indo Gangetic Plains	Sanjeev Kumar Rakesh Kumar N. Raju Singh	Nov. 2019	Oct. 2022	ICAR-RCER

Sl. No.	Project code	Project title	Name of PI & Co-PI	Start year	Comp year	Funding agency
6.4	New	Insect pest dynamics in litchi and their linking with digital tools for better management	J.S. Choudhary S.S. Mali M.K. Dhakar	July 2021	June 2026	ICAR-RCER
6.5	New	Morphological and molecular characterization of bottle gourd wilt complex	Ajit Kumar Jha J.S. Chaoudhary P. Bhavana Meenu Kumari A.K. Singh	July 2021	June 2025	ICAR-RCER
6.6	New	Evaluation of different genotypes of Water chestnut (*Trapa natans* L.) for Singhara beetle (*Galerucella birmanica* Jacoby) resistance	V.K. Padala Manoj Kumar S.M. Raut M. Monobrullah B.R. Jana	2021	2024	ICAR-RCER
6.7	New	Weed seed bank dynamics, resource-use efficiency and greenhouse gas foot print under diverse tillage production systems in Eastern Indo-Gangetic Plains	Sonaka Ghosh Rakesh Kumar R. K. Raman Saurabh Kumar Rachana Dubey S. Mondal (Associate)	July 2021	June 2024	ICAR-RCER
6.8	New	Arthropod diversity and development of weather based forecasting models for Makhana pests	Vinod K. Padala M. Monobrullah Manoj Kumar	Jan 2021	Dec 2023	ICAR-RCER
Theme- 4. Integrated Land & Water Management						
7.0	**Land & Water Management**					
7.1	ICAR-RCER /RC Ranchi/ 2014/**150**	Rehabilitation of coal mine affected areas through agroforestry interventions	P.K. Sarkar M.K. Dhakar S.S. Mali Bikash Das D. Kherwar	Sept 2014	Aug 2023	ICAR RCER
7.2	ICAR-RCER/ RC Ranchi/ 2018/**210**	Design, development and performance evaluation of solar powered agricultural equipment	S.S. Mali P.K. Sundaram J.S. Choudhary (Associate)	2018	2021 Extd. 2022	ICAR-RCER
7.3	ICAR-RCER/ DLWM/ 2018/**220**	Design and development of peripatetic fish vending cart with solar aerator	P.K. Sundaram Bikash Sarkar A Rahman	July 2018	June 2021 Extd Dec 2021	ICAR-RCER
7.4	ICAR-RCER/ DLWM/ 2018/**211**	Assessment of land use and land cover change for crop planning using remote sensing and GIS of East and West Champaran district.	Manibushan Raizada Anil.K. Singh	2018	2021 Extd 2022	ICAR-RCER
7.5	ICAR-RCER/ DLWM/ 2018/**222**	Water conser-vation under different irrigation and tillage management in rice based cropping system	Surajit Mondal Rakesh Kumar (Associate)	Oct. 2018	Sep. 2021 Extd Sep 2022	ICAR-RCER
7.6	ICAR-RCER/ DLWM/ 2018/**219**	Optimization of cropping pattern to maximize water productivity	A. Upadhyaya Akram Ahmed Anil K. Singh	Jan. 2019	June 2022	ICAR-RCER
7.7	ICAR-RCER/ DLWM/ 2018/**218**	Studies on irrigation water pricing and influencing factors	A. Upadhyaya Pawan Jeet	Jan. 2019	June 2022	ICAR-RCER

Sl. No.	Project code	Project title	Name of PI & Co-PI	Start year	Comp year	Funding agency
7.8	ICAR-RCER/ DLWM/ 2019/ **233**	Standardization of fertigation schedule in high density guava under middle Gangetic plains	Akram Ahmed Shivani Ajay Kumar T.K. Koley	Oct 2019	Sep 2022	ICAR-RCER
7.9	--	Evaluation of existing solar pump for irrigation potential in eastern region of India	A. Rahman Anil K. Singh N. Chandra Pawan Jeet	June 2020	May 2023	ICAR-RCER
7.10	ICAR-RCER/ DLWM/ 2020/ **235**	Budgeting and auditing of water for better planning and management in agriculture.	Arti Kumari A. Upadhyaya Ved Prakash Pawan Jeet Kirti Saurabh	2020	2023	ICAR-RCER
7.11	ICAR-RCER/ DLWM/ 2020/ **234**	Land feasibility analysis for rainwater harvesting planning at watershed level in Nalanda, Bihar.	Arti Kumari A. Upadhyaya Pawan Jeet	2020	2023	ICAR-RCER
7.12	ICAR-RCER/ DLWM/ 2020/ **239**	Refinement of indigenous plough and weeding rake in Eastern Hill and Plateau region	Bikash Sarkar P.K. Sundaram D.K. Raghav (Associate)	2020	2023	ICAR-RCER
7.13	-	Umbrella project on floodplains of E. India		July 2020	June 2024	ICAR-RCER
7.13(i)	--	Collection, evaluation and characterization of popular rice landraces in floodplains of eastern India.	N. Bhakta M. Monobrullah A. K. Dubey			
7.13(ii)	ICAR-RCER/ DSEE/ 2020/ **242**	Resource inventorization of floodplain wetlands in eastern India	R. K. Raman S.M. Raut Jyoti Kumar *Associates:* Jaspreet Singh			
7.13(iii)	--	Mapping of flood in eastern India and its management strategies	Akram Ahmed Arti Kumari Anil K. Singh			
7.13(iv)	New	Resource assessment and management framework for sustainable fisheries in selected wetland	V. Bharti T. Kumar Jaspreet Singh R.K. Raman S.K. Ahirwal	2021	2024	
7.14	New	Assessment of bacterial diversity and characterization of PGPR in arsenic contaminated soil	Saurabh Kumar Kirti Saurabh Rachna Dubey S K Naik (Associate)	Jan. 2021	Dec. 2024	ICAR-RCER
7.15	New	Irrigation and nutrient management of diversified rice based cropping system in middle Indo-Gangetic Plains	Shivani Kirti Saurabh Akram Ahmed	2021	2026	ICAR-RCER
7.16	New	Design and development of motorized cole crop harvester	P.K. Sundaram Bikash Sarkar A. Rahman	2021	2024	ICAR-RCER

Sl. No.	Project code	Project title	Name of PI & Co-PI	Start year	Comp year	Funding agency
7.17	New	Integrated Modeling approach for developing drought management strategies in the Sakri river basin, Bihar and Jharkhand	Pawan Jeet A.K. Singh Ajay Kumar Arti Kumari	2021	2024	ICAR-RCER
7.18	New	Determining optimum decision variables in furrow irrigated system	Ajay Kumar Pawan Jeet A. Upadhyay Sanjeev Kumar Kirti Saurabh	2022	2025	ICAR-RCER
Theme- 5. Livestock & Fisheries Management						
8.0	**Livestock and Avian Management**					
8.1	ICAR-RCER / DLFM/EF/ 2011/ **31**	Network project on Buffalo improvement	P.C. Chandran Pankaj Kumar R.K. Kamal P.K. Ray A.Dey (Associate)	June 2012	Dec. 2022	ICAR RCER
8.2	ICAR-RCER / DLFM/ 2013/ **135**	Characterization of lesser known breeds of farm animals in Eastern India	P.C. Chandran R.K. Kamal	July 2013	June 2021 Extd 2022	ICAR RCER
8.3	ICAR-RCER/ DLFM/ 2018/**202**	Assessing genetic variability in ducks of eastern states	Rajni Kumari P.K. Ray S. Dayal Ratna Prabha (IASRI) R. K. Kamal (Associate)	2018	2022	ICAR RCER
8.4	ICAR-RCER/ DLFM/ 2018/**209**	Molecular epidemiology and therapeutic management of bovine Theileriosis	Pankaj Kumar M.K. Tripathi NIAB, Hyderabad IIT, Guwahati,	2018	2021 Extd 2022	ICAR RCER
8.5	ICAR-RCER/ DLFM/ 2018/**203**	Studies on development of method for early pregnancy diagnosis in buffalo	Rajni Kumari P.C. Chandran	2018	2022	ICAR RCER
8.6	--	Outreach programme on zoonotic diseases	P.K. Ray Rajni Kumari Jyoti Kumar Scientist from BASU, Patna	2018	2021	IVRI (Externally funded)
8.7	ICAR-RCER/ DLFM/ 2019/ **231**	Development of meat and egg strains of duck suitable for backyard farming	P.C. Chandran R.K. Kamal A. Dey Rajni Kumari	2019	2024	ICAR-RCER
8.8	ICAR-RCER/ DLFM/ 2019/ **232**	Effect of genetic and non-genetic factors on prolificacy of Bengal goat	R.K. Kamal A. Dey P.C. Chandran Rajni Kumari P.K. Ray	Aug. 2019	July 2023	ICAR-RCER
8.9		AICRP on Goat Improvement	A. Dey R.K. Kamal P.C. Chandran P.K. Ray M.K. Tripathi	July 2019	Mar 2025	ICAR

Sl. No.	Project code	Project title	Name of PI & Co-PI	Start year	Comp year	Funding agency
8.10	ICAR-RCER/ RC Ranchi/ 2019/**240**	Evaluation of different tree leaves as fodder for goats	A. Dey R.K.Kamal P.K. Sarkar	2019	2022	ICAR-RCER
8.11		Evaluation of traditionally used growth promoters on production performances in pig and poultry	A.Dey Reena K Kamal Associate: P.K. Sarkar	July 2020	June 2023	ICAR-RCER
8.12	ICAR-RCER/ DLFM/ 2020/**243**	Assessment of antimicrobial drug resistance in bacteria of animal origin	Jyoti Kumar	July 2020	June 2025	ICAR-RCER
8.13	New	Reproductive abnormalities and associated common pathogens in special reference to Leptospirosis	Pankaj Kumar Abhay Kumar M.K. Tripathi A. Mukherjee Manish Kumar (IITG) S.K. Sheetal (BASU)	2021	2026	ICAR-RCER
8.14	New	Exploring genetic basis of Mastitis resistance in livestock	Shankar Dayal Rajni Kumari Jyoti Kumar P.C.Chandran M.K. Tripathi	2021		ICAR-RCER
8.15	New	Model Project and Demonstration Unit for Backyard Poultry, Livestock, Vermifarming and Moringa Integration	Dr. R.K. Kamal (PI) Dr. A. Dey Dr. P.C. Chandran Dr. Jyoti Kumar Dr. P.K. Ray Dr. V. Bharti	2021	2023	Lead centre ICAR CARI, Izatnagar (Bareill)
8.16	New	Effect of environmental exposure of arsenic in animals and fisheries in Bihar	M.K. Tripathi Pankaj Kumar A. Dey Kamal Sarma Arun Kumar (Mahavir Cancer Institute & Research Centre)	Jan, 2022 ICAR-RCER	Dec, 2026	ICAR-RCER
8.17	New	Characterization & Evaluation of Chicken Germplasm in Eastern region	Reena Kumari Kamal A.Dey P.C.Chandran	2022	2026	ICAR-RCER
9.0	**Fisheries Management**					
9.1	--	National Surveillance Programme for Aquatic Animal Disease (NSPAAD)	Kamal Sarma T. Kumar P.K. Ray Jaspreet Singh	Nov. 2015	Dec. 2020 Extd. Dec. 2021	NFDB
9.2	ICAR-RCER/ DLFM/ 2018/**201**	Culture potential of selected Indian minor carp	Kamal Sarma T. Kumar Jaspreet Singh S.K. Ahirwal	2018	2021 Extd 2022	ICAR RCER
9.3	ICAR-RCER/ DLFM/ 2019/ **221**	Biofloc technology: Exploring production optimization and economic viability for the Eastern region	Jaspreet Singh Tarkeshwar Kumar V. Bharti S.K. Ahirwal	Sep 2019	Aug 2022	ICAR-RCER

Sl. No.	Project code	Project title	Name of PI & Co-PI	Start year	Comp year	Funding agency
9.4	--	Economic feasibility of integrated prawn cum fish farming in Polyculture system in Eastern region	Tarkeshwar Kumar Jaspreet Singh V. Bharti	Sep. 2019	Aug. 2022	ICAR-RCER
9.5	--	Assessment of fish diversity and production potential in lentic inland ecosystems of North Bihar	S.M. Raut I.S. Singh Ravi Kumar Jaspreet Singh	Aug 2019	July 2022	ICAR-RCER
9.6	ICAR-RCER/ DLFM/ 2020/**241**	Effect of different manures on fish productivity	Kamal sarma T. Kumar Jaspreet Singh Jyoti Kumar A. Dey S.K. Ahirwal S. Mondal (Associate)	July 2020	June 2023	ICAR-RCER
9.7	--	Assessment of fish production potential in makhana-periphyton system in North Bihar	S.M. Raut Jaspreet Singh	June 2020	May 2023	ICAR-RCER
Theme- 6. Socio-Economics, Extension and Policy Research						
10.0	**Socio-economic Research**					
10.1	ICAR-RCER/ DSEE/ 2017/**190**	Socio-economic characterization of farmers in Bihar & Jharkhand	V. K. Yadav Pankaj Kumar Ujjwal Kumar R. C. Bharati R.K. Raman	2017	2022	ICAR RCER
10.2	ICAR-RCER/ DSEE/ 2018/**207**	Transfer and adoption of improved agricultural technologies	Ujjwal Kumar D.K. Singh Sanjeev Kumar M.K. Dhakar J.S. Choudhary	2018	2021 Extd 2022	ICAR RCER
10.3	--	Enhancing food, nutritional and livelihood security of marginal and tenant farmers in Jharkhand through need based agricultural technologies	Bikash Das V.K. Yadav R.S. Pan A.K. Jha Reena K. Kamal	June 2018	Mar 2020 Extd.Mar 2022	Farmer FIRST Project (Externally funded)
10.4	ICAR-RCER/ DLWM/ EF/ 2018/ **41**	Evaluation of farm implements and tools for small land holders	Bikas Sarkar Ujjwal Kumar P.K. Sundaram S.S. Mali Ramkewal D.K. Raghav	2018	2020 Extd June 2021	ICAR RCER
10.5	--	Value addition of principal food grains by farmers of Bihar	N. Chandra Ujjwal Kumar Dhiraj Kumar Singh P.K. Sundaram R.C. Bharati	2018	2021 Extd 2022	ICAR RCER
10.6	ICAR-RCER/ DSEE/ 2018/216	Status of food and nutritional security of rural households in Eastern India	A. Mukherjee Kumari Shubha V.K. Yadav	Oct. 2018	Sep. 2021 Extd Mar 2022	ICAR-RCER

Sl. No.	Project code	Project title	Name of PI & Co-PI	Start year	Comp year	Funding agency
10.7	--	Establishment of Biotech-KISAN Hub at ICAR RCER	Bikash Das Pawan Jeet S. Mondal A. Mukhrjee N. Raju Singh P.K. Ray R.K. Kamal J.S. Choudhary A.K. Jha A.K. Dubey D.K. Raghav, KVK Ramgarh Indrajeet, KVK Ramgarh D. Kherwar, KVK Ramgarh R.K. Singh, KVK, Hazaribagh S.K. Singh, KVK, Hazaribagh S.L. Yadav, KVK, Hazaribagh Ajit K. Singh, KVK, Ranchi Mahto, KVK, Ranchi	July 2019	June 2021	DBT
10.8	ICAR-RCER/ DSEE/ 2019/ **230**	Status of utilization of digital tools in agriculture sector in Eastern India	R.C. Bharati Ujjwal Kumar N. Chandra R.K. Raman PC, KVK Buxar Indrajeet, SMS, KVK Ramgarh D.K. Singh (Associate)	Oct. 2019	Sep. 2024	ICAR-RCER
10.9	--	DBT Biotech KISAN project on Improvement of livelihood through establishment of value chain of horticultural crops in seven Aspirational districts of Jharkhand and Bihar	Bikash Das A.K. Singh Bikas Sarkar Pawan Jeet A. Mukherjee J.S. Choudhary A.K. Jha Kaushalendra D.K. Raghav	2020	2022	DBT
10.10	--	Agri-Business Incubation Project	A.K. Singh Bikash Das S.S. Mali V.K. Yadav P. Bhavana M.K. Dhakar Dhiraj Kumar Singh T.K. Koley	2020	2025	NAIF
10.11	--	ITMU Project (NAIF Component I)	P. Bhavana A.K. Singh	2011	Long term	NAIF

Sl. No.	Project code	Project title	Name of PI & Co-PI	Start year	Comp year	Funding agency
10.12	--	Development and validation of need based technology delivery model through farmers' producer organization for eastern region of India	A. Mukherjee Ujjwal Kumar Dhiraj Kumar Singh Shubha Kumari V.K. Yadav R.S. Pan D.K. Raghav	Dec. 2019	Nov.2022	NASF
10.13	New	Model based inference on agricultural crops for food security in Eastern India	R. K. Raman Abhay Kumar Ujjwal Kumar Akram Ahmed	2021	2024	ICAR-RCER
10.14	New	Impact of e-NAM on improving marketing of agricultural produce in eastern India	D.K. Singh Abhay Kumar V.K. Yadav Naresh Chandra	2021	2024	ICAR-RCER

New and on-going activities 2021

S. No.	Title of Activities	PI
	New activities	
1.	Management of N_2O and CH_4 emission from rice-wheat cropping systems under different treatments and its mitigation measures	Saurabh Kumar
2.	Performance evaluation of canal commands in South Bihar	Pawan Jeet
3.	Studies on foliar fertilization in water chestnut	Manoj Kumar
4.	Development of clonal seed orchard of Kusum (*Schleichera oleosa*)	P.K. Sarkar
	Ongoing activities	
1.	Breeding for submergence tolerance in rice	N. Bhakta
2.	Evaluation of lentil genotypes	N. Bhakta
3.	Evaluation and development of drought tolerant rice for Eastern region	Santosh Kumar
4.	Evaluation and identification of rice genotypes for tolerance to drought stress at different growth stages.	Santosh Kumar
5.	Effect of seed size of makhana with respect to its production potential	I.S. Singh
6.	Maintenance of advance breeding lines of cool season pulses	A.K. Choudhary
7.	Genetic enhancement of Tomato for nematode and bacterial wilt resistance through Molecular markers	P. Bhavana
8.	Multi-objective optimization of integrated farming system	Akram Ahmed
9.	Scope of low cost vertical farming with particular reference to microgreens	T.K. Koley

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